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Forensic studies with human analogues: evaluation of decomposition and the use of residual odor detection dogs

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Título

Estudios forenses con análogos humanos: evaluación de la descomposición y búsqueda del olor residual con caninos

Resumen

Este libro es producto del grupo de investigación: "olfateando el conocimiento", perteneciente a la Escuela de Guías y Adiestramiento canino de la Policía Nacional de Colombia, en colaboración con el Instituto de Ciencias Forenses de la Universidad Tecnológica de Texas (TTU). El capítulo 1, recoge experimentos con análogos humanos (Sus Scrofa) detectables con equipos caninos, evaluando mediante una doble prueba ciega la sensibilidad y especificidad de los hallazgos en los sitios donde se encontraba un cadáver, con el fin de determinar la existencia del olor residual, además valida la respuesta del perro y su manejador, mediante aparatos aéreos no tripulados y cuyos perros fueron certificados con restos óseos humanos. El capítulo 2, analiza los efectos de la envoltura corporal de los cerdos frente a la tasa de descomposición, con el fin de comprender en la práctica real cuando un cuerpo es descubierto en la escena del crimen, si dicha información es crucial para que los investigadores criminales establezcan, cuál es el Intervalo Post Mortem (IPM). El enfoque académico y experimental, analiza los esfuerzos tangentes para presentar posibles soluciones a los trámites de inspección de cadáveres o los posibles sitios asociados a los hechos donde una persona puede morir. Para concluir, articula diferentes campos del conocimiento dentro de las ciencias forenses aplicadas con caninos, permitiendo una alta fiabilidad para el posterior abordaje en trabajos operativos reales de personas desaparecidas o en casos de homicidio, con el fin de e impactar los delitos que afectan la convivencia y seguridad de los ciudadanos en Colombia.

Palabras clave: Olor residual; investigación criminal; olor humano; ciencia forense; descomposición; prueba doble ciego.

Title

Forensic studies with human analogues: evaluation of decomposition and the use of residual odor detection dogs

Abstract

This book is the product of the research group "Sniffing Knowledge" which belongs to the School for Canine Guidance and Training of the National Police of Colombia, in collaboration with the Institute of Forensic Sciences of the Texas Technological University (TTU). Chapter 1 includes experiments with human analogues (Sus Scrofa) detectable by canine teams, evaluating the sensitivity and specificity of the findings at sites where a corpse was found by means of a double blind test. The test is carried out in order to determine the existence of residual odor. It also validates the response of the dog and its handler using unmanned aerial devices and uses dogs who were certified with human bone remains. Chapter 2 analyzes the effects of the external envelope of pigs against the rate of decomposition in order to understand, in real practice when a body is discovered at a crime scene, if such information is crucial for criminal investigators to be able to establish the Post Mortem Interval (IPM). The academic and experimental approach analyzes tangent efforts to present possible solutions to corpse inspection procedures or the possible sites associated with the events in which a person might die. To conclude, it articulates different fields of knowledge within the forensic sciences applied with canines, allowing high reliability for the subsequent approach in real operational work of missing persons or in cases of homicide in order to have an impact on the crimes that affect coexistence and citizen security in Colombia.

Keywords: Residual odor; criminal investigation; human odor; forensic science; decomposition; double blind test.

The Autors

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He a veterinarian doctor (DVM) graduated from the Universidad de La Salle (ULS) and is currently a lecturer there as a doctoral thesis tutor. Rojas-Guevara is a Specialist in Police Service at the National Police of Colombia, a Master in Veterinary Sciences from ULS and a PhD in education from Nova Southeastern University. He currently works as an Operational Commander of the Guania Police Department. Dr. Rojas has served as a teacher, instructor, evaluator and certifier of canine equipment in the National Police of Colombia (NPC), evaluating dog teams which detect narcotic and explosive substances in the United States of America, the Netherlands, and Paraguay. Currently, he is a Major in the NPC with 19 years of active service. He has held positions as commander of a police Immediate Attention Center (CAI) in Bogota, commander of the canine unit in Bogota, head of dog breeding, teacher, head of an academic area, subcommander of a station, dean, head of the information and dissemination group for research at the Graduate School of Police, editor of the journal Logos *Ciencia & Tecnología* (indexed by Publindex in category B), and Operational Commander of Citizen Security. Currently, he directs a master's thesis at the public security program of the Graduate School of Police and his research interest is assessment instruments for cadaver dog selection, certification, and their detection capabilities, as well as their performance in detecting associated crimes such as rape, illicit drug-trafficking, and the evaluation of canine detectors of animal species. Part of this research proposes the Animal Species Trafficking System (SITEA). His previous research tends to contribute to best practices and performance improvement of canine teams. Dr. Rojas has published several articles in indexed magazines and his latest book *Police Canine Teams: Importance of Selection Criteria, Training, Certification and Performance* was a work funded by Texas Tech University in partnership with the NPC. He is currently the director of the research group "Sniffing Knowledge," categorized as an associate researcher and recognized by the Ministry of Science, Technology and Innovation. The group actively participates in think groups, interest groups and projects related to cadaver dogs, dog teams that detect different animal species (illegal traffic of reptiles, mammals and birds), the standardizing of protocols related to these, and validating them with double-blind tests. Email: jorge.rojas@correo.policia.gov.co

Paola A. Prada-Tiedemann

Dr. Tiedeman received her PhD. in chemistry with an emphasis in forensic science from Florida International University in 2010. She was awarded the Postdoctoral Research Fellowship of the Intelligence Community (IC) in 2010, funded by the Office of the Director of National Intelligence. Her postdoctoral studies have brought together interdisciplinary areas such as chemistry, animal behavior, and national security to address critical issues for effective intelligence operations and for the country's defense capabilities. Dr. Tiedeman has worked extensively on developing instruments and methods for identifying human odors for criminal investigations; she has also worked with canine odor detection in the context of optimizing odor collection techniques for odor training purposes. Her research interests include evaluating human odor volatile compounds as a forensic discriminating tool as well as testing target odor analytes on various samples of forensic importance for optimal performance of biological (i.e., canine) detector systems. She has worked with national and international law enforcement and government agencies to help develop better training and techniques in various areas of odor detection. She is the author and co-author of numerous magazine publications, book chapters, on book devoted entirely too human odor-based evidence, and another devoted to the selection, training, and certification criteria for canine equipment. Dr. Prada has been a speaker and presented her research in various national and international forums. She is a member of the American Chemical Society and the American Academy of Forensic Sciences. Email: paola.tiedemann@ttu.edu

Katherine C. Titus

She is a college student at Texas Tech University working toward a bachelor's degree in sociology. Her interest in this research is to determine "when a body is discovered at the crime scene" and to obtain crucial information for criminal investigators to establish the Post Mortem Interval (IPM). This is a challenging process because the human decomposition process is highly susceptible to the influence of a wide variety of factors. Therefore, it is a very exciting topic, which she will probably continue investigating with the advice of Dr. Paola Prada and Dr. Jorge Rojas-Guevara.

Juan David Córdoba Parra

He is a veterinarian from Universidad La Salle ULS (2008), Master of Science in Animal Health from Universidad Austral de Chile (2010), Marketing Management Specialist from Universidad Politécnico Grancolombiano (2016), and currently a PhD student in Agro-Sciences at ULS. He has worked since 2011 as a teacher in the area of animal health and welfare at the Universidad de Ciencias Ambientales y Aplicadas (U.D.C.A.) and at ULS. He is currently a full-time lecturer and research coordinator in the Animal Welfare and Ethology Specialization program of the Fundacion Universitaria Agraria de Colombia (Uniagraria). He has been working since 2016 as a veterinarian consultant and vet director at Legal & Tierras Consultores S.A.S. He also performs private consultancy in animal health and welfare in the departments of Cundinamarca, Boyacá, and other regions of Colombia.

Gabriel Antonio Bohórquez

He is an Intendent at the NPC with 21 years of experience in citizen security and coexistence, operational security with K-9 teams, a teacher and social researcher in the responsible possession of pets and animal welfare, and a psychologist at the Universidad Nacional Abierta y a Distancia (UNAD). He is a master's degree candidate in education at the Universidad Militar Nueva Granada (UMNG), a Professional Technician in Comprehensive Canine Security at the School for Canine Guidance and Training (a program accredited with high quality by the National Accreditation Council (CNA) of the Colombian Ministry of Education), a professional technician in human management and community development graduated from SENA technical school. He has experience as a research professor at the National Directorate of Schools, the NPC, and received the recognition of "junior researcher" from COLCIENCIAS. He is also a K-9 instructor graduated from the Gendarmerie of Chile, and a K-9 instructor of the NPC. He has participated in the creation of the canine assisted therapy program at the National Police, of K-9 teams that detect wildlife in Colombia, and he has collaborated as co-author of the book *Manual for canine training at the National Police of Colombia,* the book *Footsteps of the canine guides of the National Police of Colombia* and the book *Use and training of K-9 wildlife detectors teams.* He has been a lecturer and speaker on issues of animal welfare and responsible pet ownership.

Acknowledgments

To almighty God, for allowing us to write this book, constructed by teamwork between Texas Tech University (TTU), the Institute for Forensic Science (IFS), the research group "Sniffing out Knowledge" of the School for Canine Guidance and Training of the National Police of Colombia (ESGAC) and the Fundación Universitaria Agraria de Colombia (Uniagraria).

Mayor Jorge Ulises Rojas-Guevara: In the 19 years that I have been an officer for the police, I must stop for a moment in the process of editing and co-authoring *of The Human Scent in Criminal Investigation: Operational Challenge for Forensic Sciences and canine detection teams* so that I can ascertain that I was able to carry out this task thanks to God and the support of my family, which allowed me to connect the whole interdisciplinary work team to be linked and work together.

Thanks to the authors, who with their knowledge, experience, and synergy, accessed and built the 2 chapters. To my wife Edna Tatiana Hernández Maldonado and my son David Alejandro Rojas Hernández, who are the ones who motivate me, make me happy, give me peace and unconditional love, and keep me down to earth so I can be a better human being every day, to my parents: Carmen Guevara and Pedro Jesús Rojas Bernal, for my life, valuer-oriented education, love for animals and nature, and for cultivating my spirituality and guiding, advising and understanding my responsibility as a public servant. Thanks to you I am able to dream of a Colombia strengthened through citizen security and coexistence, founded on the three institutional pillars of the police: 1) to consolidate a police for the people, 2) that is transformed to serve better, and 3) that thinks and cares about its police officers. The previous policies have allowed me to be a better person, friend, husband, father, brother and son, through unconditional family love and the support of the NPC. To my brothers Sergio Federico Rojas Guevara and my colonel Pedro Javier Rojas Guevara of the glorious national army, for being my blood ties, my friends, and for helping me several times to make different decisions. Thanks again to God, for making us understand the strong bond between animals and humans represented in saving lives, finding out part of the truth, or trying to solve crimes as workers for justice through the discovery of corpses, mitigating the pain of the loss of a loved one. Please bless all members of the public force and the canine teams who constantly fight and who, through their profession, demonstrate their determination, honor, and courage in facing criminal organizations every day. These people protect us in the different urban and rural contexts of law enforcement. Police and military, guaranteeing citizen coexistence and safety.

Doctor Paola A. Prada: I want to thank the NPC and the Texas Tech University's (TTU) Master's Program in Forensic Science for managing to write this book, which provides tools that can permeate future students and researchers with continuing studies focused on finding the truth through my work and advice to some of the students, teachers and members of the educational community of TTU and the National Police of Colombia. Thanks to my husband Chris Tiedemann Jr. and my son who is about to be born, for helping me to understand the work of the police in Texas and around the world, as they help with the constant effort to build coexistence and citizen safety. Thanks to my friends, collaborators, students, managers, my mentor Dr. Keneth Furton, and all those who daily involve me in understanding forensic science and especially in the fundamental work of police-work dogs.

The authors would like to thank Dr. Brittany Backus from the Animal Care Services at Texas Tech University's Animal and Food Sciences Department and Mr. Will Winters from Wintex Farms for the kind donation of pig carcasses to be used in this study without whom this experiment would not have been possible.

In honor of the Colombian police officers who have lost their lives or have been injured during their institutional service and who have been victims of the armed conflict, being recognized as heroes of Colombia.

Forward

How many cadaver dog handlers expect to be contacted by an organization called the National Commission for the Search of Missing Persons? How many expect to provide data for an Information System of the Network of Disappeared Persons and Corpses? The authors of this book state:

In Colombia, the search for buried bodies is carried out daily by digging trenches and using a stainless steel probe in places where informants report that remains may be; unfortunately, judicial investigations are often unsuccessful and uncertain as to whether the remains were at the examined site or not.

Cadaver dogs come into play. The authors introduce their work by referring to a training program initiated by the National Police of Colombia, Training of Canines in Search of Corpses, and Mass Graves, specifically instituted because of the need to exhume the victims of armed conflict in Colombia. I cannot think of a book dealing with detection dogs that includes terms such as genocide, forced disappearance, torture, or that discusses a National Registry of Disappeared Persons.

Yet this book does

Finding bodies is one thing, finding mass graves another. Both can involve the use of detection dogs. When a person is reported missing, tracking dogs may be used to find out where that person has gone, say by following a path from the house where the person was last thought to be, a path not found by the police, who must rely on what they can see, but instead "seen" by a dog relying on its sense of smell. If the suspicion arises that the missing person was murdered, cadaver dogs may be brought in to find a body or to identify a location where a body may have been placed for a time before being disposed of elsewhere. Of course, in a given case, cadaver dogs may both find the body, say in a shallow grave and also identify a location, such as the trunk of a car, in which the body may have been transported before being buried in the grave.

These are matters standard to police canine units with tracking and cadaver dogs and no political questions generally arise. But what if the missing person is a political figure, with ruthless enemies in high places, having resources not available to ordinary criminals? Or what if a cadaver dog finds a mass grave during or after a period of insurrection and conflict? This may result in an investigation of crimes that certain groups with political power may not want to solve.

There are risks to handlers and their dogs, that most readers of this book—including this writer—have never dreamed of. When I was asked to write a forward to this book, it was an unusual aspect of its coverage that decided me on accepting the request of the authors that I explain to potential readers why they should read this book.

The authors of this book, while focusing on the olfactory functions of detection dogs, have highlighted situations where both dogs and handlers may find themselves producing evidence that not everyone will want to be publicly revealed. That is, the information produced by the dogs may not just be a threat to the individuals responsible for a specific crime or crimes, but also for those who believe that the political persuasions of the perpetrators need to be supported regardless of the extremes to which the perpetrators went in eliminating opposition to those persuasions. Of course, being a detection dog handler can produce certain risks, when the handler and dog discover evidence of corporations polluting environments, killing endangered animal species for markets in ivory, transferring pelts of baby seals across national borders and in many other situations where handlers take detection dogs.

What I am saying is that emphasizing such results from the work of detection dogs and increasing the effectiveness of those dogs, requires courage, the courage to see that dogs are not just friends of individual owners, of individual police handlers, but also of society itself. Man's best friend is sometimes also human society's best friend. The authors here know that the dogs they are working with, can produce evidence not only of crimes against people, but of crimes against humanity.

Being scientific does not mean being heartless. The authors include the text of the Universal Declaration of Animal Rights. This leads to a discussion of positive reinforcement in canine training. They realize that by being our best friend in situations where their results may pose risks to certain elements of society, dogs and their handlers may become targets for those elements just as if they were political dissidents. Empathizing with dogs in this way is not something most of us working with trained dogs have ever had to choose. As I say, courage.

I am writing this in a time—summer of 2020—when scientists the world over are finding that political forces are arrayed against them. Some scientists might say that it is not a time to "make waves" but rather that it is best to keep to the narrow bounds of laboratories and talk to other scientists only in the restricted visibility of research journals. The argument is that it is not the function of scientists to tell politicians what to do. Yet, if the evidence of science has implications for public welfare, is it not the obligation of scientists to speak out? The authors of this book are not afraid to do so.

This work will take the attentive reader into new areas and will reveal new possibilities that will be useful for dog researchers, police dog handlers and lawyers the world over. It deserves our attention.

John Ensminger, JD, LLM, Esq.
31 July 2020
Rhinebeck, New York

Contenido

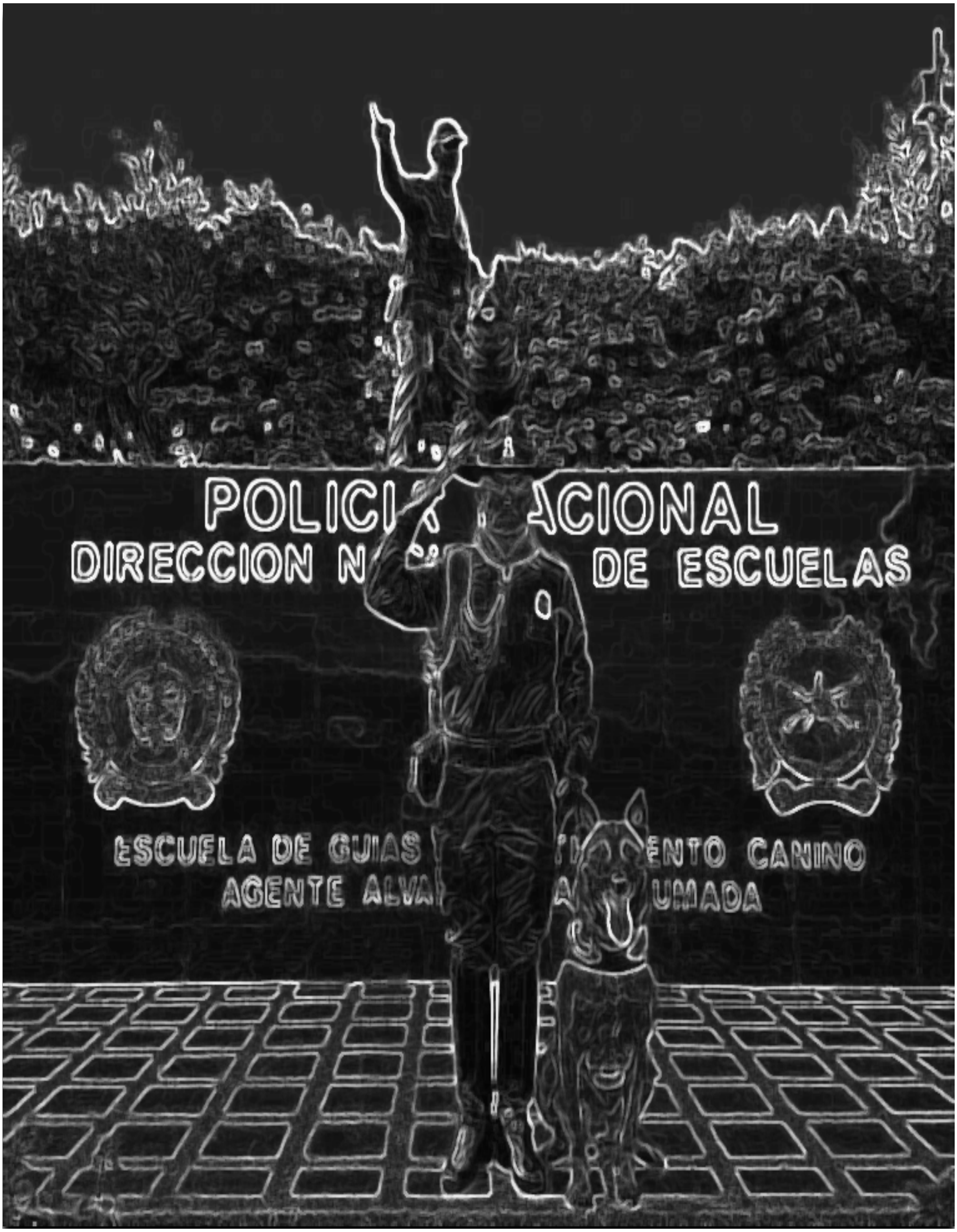
Figure List

Table list

List of acronyms

Acronyms	Meaning
AAFS	American Academy of Forensic Sciences
ANSI	American National Standards Institute
ASB	American Standard Board
CNBPD	Commission for the Search of Missing Persons
DIJIN	Directorate of Criminal Investigation and Interpol
DISEC	Directorate of Citizen Security
DVB	divinylbenzene / carbon / polydimethylsiloxane
GC	Gas chromatography
HRD	Human Remains Detection Dog Training Protocol
HS-SPME	Headspace Solid Phase Microextraction
ICA	Colombian Agricultural Institute
IMSIon	Mobility Spectrometry
PMI	Post Mortem Interval
OIE	World Organization for Animal Health
MBU	Urgent Search Mechanism
MS	mass spectrometry
Methylthio	pyridine, 3-methylthio-1 propanol and methyl
NPC	National Police of Colombia
NPV	Negative Predictive Value
PCA	Principal Component Analysis
PMI	postmortem interval
PONAL-ESGAC	School for Canine Guidance and Training, of the NPC
PPV	Positive Predictive Value
RND	National Registry of Disappeared Persons
SIRDEC	Information System of the Network of Disappeared Persons and .. Corpses
SPE	Solid Phase Extraction
SPME	Solid Phase Micro Extraction
TD	Thermal Desorption
TDS-GC-MS	thermal desorption with gas chromatography and spectrometry of masses
TOFMS	Time-Of-Flight Mass Spectrometry
TTU	Texas Tech University
UDAR	Universal Declaration of Animal Rights
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIAGRARIA	Fundación Universitaria Agraria de Colombia
UNODC	United Nations Office on Drugs and Crime
UV	Ultra Violet
VOC	Volatile Organic Compounds

Figure 1.
National Police of Colombia - School of Canine Training Canine Unit.



1. Training protocol, certification and operational procedure for canine teams detecting human remains

Introduction

In 2007, the National Police of Colombia initiated the Training of Canines in Search of Corpses and Mass Graves program, responding to a need to support the work of the Judicial Police of Colombia, members of the Prosecutor's Office and other institutions in charge of carrying out the processes of exhumation of victims of the armed conflict in the country. However, in 2019 the research project "Olor Residual de Cadáveres y su Detección por Equipos Caninos" ("Residual Odor of Cadavers and their Detection by Police K-9 Units") was developed. The project aims to identify the presence of residual odor caused by decomposition of pig carcasses in tropical soil areas by using gas chromatography and canine detection with the goal of varying decomposition stages and exposure time as a contribution to forensic science and canine operating procedures. The training protocol and operational procedure of K-9 equipment for detecting human remains is generated as a result of this research project, aimed at strengthening police service with canines, especially in criminal investigation settings where the lives of human beings are compromised.

1.1 Canine- human Synergy

The human-dog relationship began 20,000 to 40,000 years ago and it is believed that approximately 15,000 years ago, some dogs were fully domesticated for protection and hunting purposes (Cristescu, Miller & Frèrea, 2019). According to Lit et al. (2011) and Ferry et al. (2019, p. 12), in the process of domestication, dogs have changed and adapted their behaviors in order to approach humans, developing skills to respond to the commands and signals given by their handlers.

Udell, Dorey & Wynne (2010) and Lazarowski (2018, p. 1), proposed a domestication hypothesis that stated that the sensitivity to human social signals that occurred during this process led to a better understanding and innate response to human behavior, supported by evidence that dogs outperform wolves, their closest ancestor, the two-stage hypothesis proposes that these abilities are not innate and require: 1.) Socializing with humans during the critical window of development and 2.) Learning and gaining experience with relevant human gestures, backed by evidence that experience can greatly improve these skills. Although the debate continues, both phylogeny and ontogeny are important for the development of dogs' ability to use human social information (Lazarowski, 2018).

In the past century, the unique roles of dogs working with and for humans have expanded; these animals now play vital roles in supporting the concept of "One Health," where the health of animals, humans and the environment are transposed (Otto, Cobb & Wilsson, 2019), with numerous studies that have shown how pets positively influence human health and well-being (Gómez, Atehortúa & Orozco, 2007). These working dogs include guide dogs, which serve to guide and support people in their daily lives, detection dogs, that use their sense of smell to identify dangers or odors of interest (for example explosives, drugs, diseases, and invasive or endangered species), and working dogs, which work with the police and the army to provide security (Otto, Cobb & Wilsson, 2019).

Fjellanger et al. (2002) and Blom (2013) report that there are 700 mine detection dogs in the world distributed throughou 23 countries. At the beginning of the 20th century, the police and the army began to use canine special units. The detection of accelerators by dogs was used for the first time in field tests in 1987. Ever since the World Trade Center bombing in 1993, dogs have routinely been used for search and rescue. Other areas where dogs are considered superior to other methods include narcotic detection and termite searching in buildings (Blom, 2013). Furthermore, within the operational field, dogs are used as "biological detectors" to sense native species of aquatic wildlife to determine their natural distribution in addition to the number of invasive species observed (Quaife, 2018). This indicates that the monitoring techniques of these species have significant potential use in different environments (Shields & Austin, 2018).

The term "biological detector" is applied to animals (Peñaranda & Asemsio, 2008) and plants (Volkov & Ranatunga, 2006; Palagin, Grusha, Antonova, Kovyrova & Lavrentyev, 2017) that can be trained, conditioned, or genetically modified to detect key molecules in the environment. Detecting "target odors" plays a key role for a variety of purposes within the forensic setting (Castillo, 2016). Therefore, research using animals allows for optimal and efficient detection of odors in field work (Prada & Furton, 2018). Due to the high specificity and sensitivity, fast response, low cost, relative compact size, and operational easw of use, biosensors are an important tool for the detection of chemical and biological components and for monitoring clinical, food, legal, and environmental components (Frederickx, Verheggen & Haubruge, 2011, p. 449).

On the other hand, biomedical odor detection dogs currently identify the odor profiles of diseases such as cancer and diabetes, psychological disorders, endocrine diseases such as Cushing's syndrome and thyroid disorders, cirrhosis, Candida esophagitis, sinusitis, alcohol abuse and other pathogenic microorganisms (Lippi & Cervellin, 2012). Given that biomedical odor detection is a potential tool to identify diseases, it is comparable to a health technology (Koivusalo & Reeve, 2018).

As noted above and according to the United Nations Office on Drugs and Crime (UNODC), there is no set limit to the number of "target smells" that a trained dog can detect, but 12 to 15 smells is considered a reasonable amount for any dog, considering the time required for training and achieving a persistent and efficient response. Furthermore, the intensity of odors and their frequency can affect the dog's willingness to search for them, taking into account that rare and weak odors can be ignored in favor of other stronger and more common ones (UNODC, 2016). In regards to alert responses by the dog when detecting the target odor: the command "stay still" in which the dog remains standing with its nose on the object and "paralyzes" himself, has been studied less in literature regarding biomedical detection, due to the possibility that dogs that carry out this type of alert may be misinterpreted since they are obligated to keep their nose on the sample, unlike dogs that "feel alert" and receive their reward (Essler, Wilson, Verta, Feuer & Otto, 2020).

It should be noted that odor-detecting animals can sometimes deliver false negative or positive diagnoses, as a result of a failure in the link between detection and trained alert response. A false negative response can be critical in scenarios such as searching for a living person or detecting explosives. Therefore, the duration of sniffing and the number of episodes of smells recorded in an odor detection task can be quantified, demonstrating that the duration of tracking of the truly negative results is significantly shorter than that of false negatives, true positives and false positives (Concha et al, 2014). In a study of environmental reservoirs involved in the transmission of *Clostridium difficile* infections, the detection of odors by canines has shown a promising ability to quickly classify hospital surfaces and equipment, being able to implement possible mitigation strategies (Li et al, 2019).

Another example was the evaluation of 10 canines trained for the detection of a severe exotic phytobacterial tree pathogen, *Candidatus Liberibacter asiaticus*, with a precision of 0.9905, sensitivity of 0.8579, and specificity of 0.9961 (Gottwalda et al, 2020). In cases of sexual assault, the detection and identification of semen is extremely important since it serves as evidential material. So the performance of detection dogs was compared with 1.) Forensic light sources, 2.) The semen RSID field kit, and 3.) the enzymatic acid phosphatase test, all used on semen deposited in different types of fabrics, showing 100% sensitivity and specificity on the part of dogs and a sensitivity and specificity of 76.3% and 100% for test 1, 81.6% and 100% for test 2 and 92.1% and 100% for test 3 (van

Dam, Schoon, Wierda, Heeringa & Aaldersa, 2019), representing a high value for the use of these animals in such scenarios.

Additional studies have suggested that this association has had profound consequences, as the brains of dogs and humans have evolved (Wang et al, 2013). Dogs have become indispensable in multiple programs, including the detection of drugs and explosives (Jamieson, Baxter & Murray, 2017; Lazarowski et al, 2018) based on the fact that their sense of smell is 10,000 to 100,000 times more sensitive than humans (Jenkins, DeChant & Perry, 2018). For these reasons, Helton (2009) and Johnen, Heuwieser & Fischer-Tenhagen (2017), mention that dogs have been classified as the "gold standard" test of odor detection technology.

The way to make a dog find specific odors, includes different types of tests for training and control of odor-detecting dogs, among which are: 1.) non-blind test: both the expert who supervises the tests and the dog trainer know the state of concurrence of odors; 2.) partially blind test: only the expert knows, but not the trainer; and 3.) double blind test: neither of them know the information. It is to be highlighted that it is important to keep in mind that no "blind" exercise is useful during the initial phase of training, when it is required to offer an immediate reward for obeying an order and rewarding a result (Ferry et al, 2019).

It should be noted that domestic dogs, *Canis familiaris,* are very sensitive to human communication signals in addition to their olfactory ability; they can use gestures to help locate hidden rewards (Udell, Giglio & Wynne, 2008). This ability is believed to be the product of genetic and behavioral selection, allowing dogs to adapt to life with humans (Breed & Moore, 2015). It was shown that a dog's responsiveness to human cues decreased with age, while the ability to locate reward through odor increased and that lack of susceptibility to misleading social cues was predictive for future success as a detection dog (Lazarowski, Rogers, Wagoner & Katz, 2019).

The crucial qualities needed by these animals for training procedures that must be considered along with the characteristics and training of the dog are reliability, tranquility, ability to focus on the task (attention), motivation, endurance, good health and ease of handling (Ferry et al, 2019). Factors affecting overall individual performance should be considered and evaluated, such as temperament, arousal, handler-dog relationship, training regimens, housing and handling of odor detector dogs; learning and performing specific tasks, and premature birth, as well as limiting performance factors such as the need to gasp in hot environments at work (Troisi, Mills, Wilkinson & Zulch, 2019).

Despite the demonstrated ability of dogs to discriminate and identify human odor with the alignment technique, the admissibility of such tests is not systematically accepted by the forensic community and the courts and is often questioned in some countries, which is related rigorous procedures and continuous training lead to high sensitivity and specificity in the olfactory matching tasks of human samples (Marchal, Bregeras, Puaux, Gervais & Ferry, 2016).

For the above-mentioned reason, the protocols applied to dogs during training and certification are fundamental, as this ensures that the work carried out is effective and reliable and through its continuous application, is able to permanently obtain similar successful results every time they are applied (NPC , 2016). On the other hand, individual variations between dogs suitable for different job roles should be considered, as they should not be excluded solely because of their breed. In addition, consideration should be given to how detrimental it is to change a dog's handler for their well-being and performance (Jamieson, 2019). In figure 3, the institutional cross-sectional impact of the canine service in the National Police of Colombia is shown, along with the social effects that are inflicted by criminals including their causes and effects.

The Brownell-Marsolais Scale, used for the evaluation of canine search, rescue, and disaster response candidates (Beebe, Howell & Bennett, 2016), evaluates parameters such as: inherent ability (between people and other canines), motivation and management (commitment to reward, prey management, hunting unit, dog-handler interaction), nervousness (tested on different surfaces and environments), obedience, barking behavior, directionality, agility and comfort among debris, searching in rubble, and sociability, among others. Likewise, it is essential that both coaches and academics share a common language and an understanding of reinforcement and punishment and its effects (table 4) (Troisi, Mills, Wilkinson & Zulch, 2019). According to Kleen et al. (2006) and Troisi et al. (2019), animals are motivated by intrinsic and extrinsic factors and these have different underlying mechanisms (p. 56).

1.2 General operational impact of the canine police service

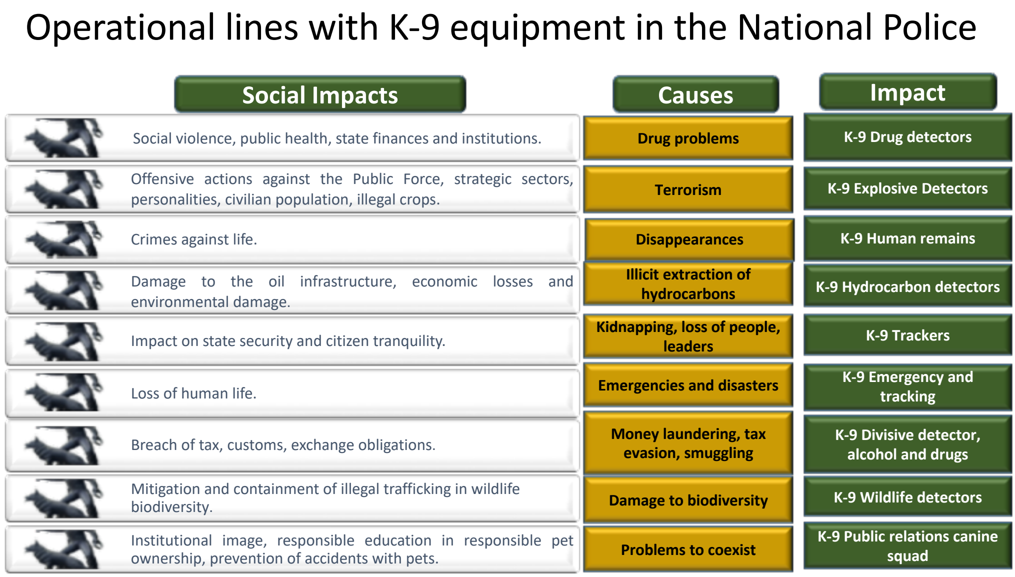
The National Police of Colombia has different specialties or lines of service with canine teams and each of these lines had an impact on determining the main social and environmental problems that can affect coexistence.

1.3 Canine Training Protocols

1.3.1 Ethical principals in canine training teams detecting human remains

Knowledge and application of the universal declaration of animal rights (Figure 4), which was adopted by the International League for Animal Rights and by the National Affiliates of Leagues after the 3rd Meeting on Animal Rights, London, from September

Figure 2.
Institutional cross-sectional impact of the canine service in the National Police.



Note: NPC

Table 1.
Definitions of positive and negative reinforcement and punishment, with examples related to dogs.

Action	Definition	Exalte
Reinforcement	Procedures that strengthen or increase the long-term probability of behavior.	A specific desirable action is recommended.
Positive reinforcement	A response is followed by the appearance or increase in intensity of an attractive (appetitive) stimulus or event.	If a handler asks a dog to sit down and the handler gives him food, a toy, etc., after the correct behavioral response, the dog is likely to sit down again when the same signal is provided.
Negative reinforcement	A response is followed by the removal or decrease in intensity of an aversive stimulus or event.	The pressure applied to a dog's head through the head collar is relieved when the dog turns the head in the desired direction, making the dog more likely to turn in the desired direction.
Punishment	Procedures that weaken or decrease the likelihood of long-term behavior	A specific undesirable action is discouraged, but no specific desirable alternative is recommended.
Positive punishment	A response is followed by the appearance or increase in intensity of an aversive stimulus or event.	A dog receives an electric shock when it is thrown onto the lead towards sheep with such intensity that the dog avoids them in the future.
Negative punishment	A response is followed by the removal or decrease in intensity of an attractive stimulus or event.	A dog barking for the attention of its owner is completely ignored and therefore less likely to perform this behavior in the future.

21-23, 1977 is necessary to carry out work with animals given the ethical requirements that each person working with animals must possess. The declaration was proclaimed on October 15, 1978 by the International League, the National Leagues and the people associated with them. It was approved by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and, later, by the United Nations proper (UN) (UNESCO, 1978; Nava-Escudero, 2015; Capacete- González, 2018).

In addition, in 2003, the Government of the Philippines organized an intergovernmental conference that produced a draft declaration that agreed on four principles that could serve as the basis for a Universal Declaration of Animal Rights (UDAR) as agreed to by 21 delegations (19 countries, a community in political union with the United States [Saipan] and a regional organization [the European Commission] (United Nations for Food and Agriculture, 2010). It is vital to know and apply this with the support of the World Organization for Animal Health (OIE) with respect to animal welfare, which is considered as "the physical and mental state of an animal in relation to the conditions in which it lives and dies" (Figure 5) (World Organization of Animal Health (OIE), 2004), in addition to the five freedoms, recognized by the OIE (World Organization for Animal Health, 2020).

1.3.2 The handler's training

According to the preparation of the team (canine team is understood as handler and dog), canine handler training should include: 1.) The ability "read to the canine" (interpret the behavioral changes of the canine to particular stimuli). 2.) Acquisition and processing of odor / aroma by the canine, 3.) Education on the various environmental conditions that affect odor / odor dispersion, 4.) Canine handling techniques (ex. voice inflection and handling guide); 5.) Rewarding the canine, 6.) Education on aspects of cognitive bias, 7.) First aid for canines and handlers, 8.) Fitness for the canine and the handlers 9.) Relevant legal aspects which include: odor/odor dispersal effects, pertinent jurisprudence, preparation of legal documentation, and preparation for testimony in the courtroom (ANSI-ASB, 2020).

It is essential to know and implement what is regulated in Law 1774 of January 6, 2016, "through which the Civil Code, Law 84 of 1989, the Penal Code, the Code of Criminal Procedure and other provisions are promulgated, giving the quality of sensitive beings to animals Article 3. Principles (Colombian Congress, 2016), corresponding to work with animals, in the specific case of canines, it is a priority to be aware of the principles of protection, welfare and solidarity with animals (figure 6). Strict compliance with the provisions of Law 1801 of 2016 (July 29), by which the National Code of Police and Coexistence is issued, in relation to the possession and coexistence with animals (Colombian Congress, 2016).

Figure 3.
Universal declaration of animal rights.

Article 1. All animals are born equal to life and have the same rights to existence.

Article 2. Every animal has the right to be respected. All animals have the right to human attention, care and protection.

Article 3. No animal shall be subjected to mistreatment or cruel acts

Article 4. On the freedom and vital use of wild species

Article 5. Every animal that traditionally lives in man's environment has the right to grow at their natural rate and have the freedom to express behaviors appopriate to their species

Article 6. Every animal chosen by man as a companion has the right to have its life span be in accordance with its natural longevity.

Article 7. Every working animal has the right to a reasonable limitation of time and intensity of work, to a restorative diet and to rest.

Article 8. Animal experimentation involving physical or psychological suffering is incompatible with the rights of the animal.

Article 9. On the treatment of animals raised for food

Article 10. No animal will be exploited for man's recreation.

Article 11. Any act that involves the unnecessary death of an animal is a biocide, that is, a crime against life.

Article 12. On the genocide of wild animals

Article 13. A dead animal must be treated with respect.

Article 14. Animal rights must be defended by law, as well as human rights.

Figure 4.
The five domains proclaimed by the World Organization for Animal Health (OIE).

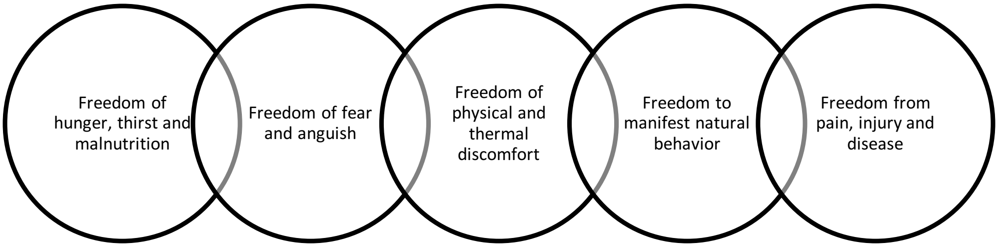
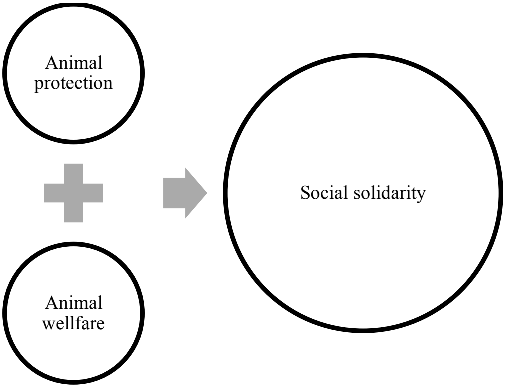


Figure 5.
Safety working pledges when using canines.



1.3.3 Evaluation of canine working behavior

The reliability and validity of the behavioral tests used to assess critical behavioral characteristics must be obtained in order to carry out the selection of working dogs (Brady, Cracknell, Zulch & Mills, 2018). Table 2 shows the categorization of the behavior of working dogs.

1.4 Initial canine training

After the selection of the dog, according to the response of the behavioral variables, ANSI-ASB (2020) reports that the initial training of the canine must include different tests, shown in Table 3.

Within the basic learning processes related to dog training, two processes are recognized: classical conditioning and operant (Pérez & Cruz, 2003; Barrera, Elgier, Jakovcevic, Mustaca, & Bentosela, 2009; Carballo, Freidin & Bentosela, 2015). The first refers to

Table 2.
Categorization of working dog behavior.

Categorization of assessed behavior within the working dogs based on literature in order to create groups created on a biological basis for behavior			
Main effect	**Behavioral characteristics**	**Examples of methods used**	**Examples of test parameters**
Positive emotional state	Will to work	Search focus and motivation	Uninterrupted search for an object (Slabbert & Odendaal, 1999; Sinn etal, 2010) / search unit (Mcgarrity, 2016).
			Speed and hesitation when contact is made with object (Slabbert & Odendaal, 1999; Svobodová et al, 2007; Asher et al, 2013).
			Effect of distraction on behavior when another dog is present (Batt et al, 2008).
			Readiness to return a ball/ object (Wilsson & Sundgren, 1998; Mcgarrity, 2016), training capacity (Foyer et al, 2014; Harvey et al, 2016) and willingness-to chase or follow light (Foyer et al, 2014).
	Human- led social behavior	Behavioral greeting, willingness to get close to strangers, chasing	Readiness to greet a stranger (Wilsson & Sundgren, 1998; Svobodová et al, 2007; Svartberg, 2002).
			Posture/body behavior during exam, petting/ examination (Asher et al, 2013; Harvey et al, 2016).
	Object- directed game	Play with toys/ chasing	Vocalization and behavior during play (Sinn et al, 2010).
			Time needed to drop a toy (Sinn et al, 2010) and latency to grab a toy (Batt et al, 2008).
			Interest for a toy and intensity / tugging (Svartberg, 2002; Svobodová et al, 2007).
			Immediate reaction towards a toy (investigates first or begins to play) (Wilsson & Sundgren, 1998).
			Response to toy versus the evaluator (Asher et al, 2013).

Categorization of assessed behavior within the working dogs based on literature in order to create groups created on a biological basis for behavior

Main effect	Behavioral characteristics	Examples of methods used	Examples of test parameters
Negative emotional state	Aggression towards humans	Impulse to defend, aggression led by strangers	Posture, behavior (Sinn et al, 2010) and vocalizations towards the evaluator (Sinn et al, 2010) / strangers (Foyer et al, 2014).
			Velocity and biting force towards the evaluator (Sinn et al, 2010)
			Level of aggressive response when provoked (Slabbert & Odendaal, 1999), startled (Svartberg, 2002) or addressed (Sherman et al, 2015).
	Retreated approach	Investigation- exploration	Exploratory behavior when startled by visual or acoustic stimuli (Sherman et al, 2015; Tomkins et al, 2011; Svartberg, 2002) and in a novel environment (Weiss & Greenberg, 1998), or with new objects (Barnard et al, 2017; Harvey et al, 2016).
	Sensitivity to aversive	Sensitivity to noise	Stability/ security during weapons testing, marking of behavioral postures (Sinn et al, 2010; Slabbert & Odendaal, 1999; Gruen et al, 2015).
		Testing on response to shooting and sudden appearance	Avoidance reaction during weapons testing (Svartberg, 2002).
			Shock reaction during audio and acoustic stimulus (Svartberg, 2005; Sherman et al, 2015; Asher et al, 2013; Svobodová et al, 2008; Svartberg, 2002; Weiss & Greenberg, 1998; Gruen et al, 2015; Weiss, 202; Foyer et al, 2016)
			Latency to recover from noise (Batt et al, 2008; Tomkins et al, 2011).

Note: Brady, Cracknell, Zulch, & Mills (2018).

the involuntary response that results from experiences that occur before the response. This process can be counter conditioned, desensitized and adapted (Makowska, 2018), while the second one deals with the evaluation of behavioral changes that occur as a result of experiences that happen after the response and this includes reinforcements and positive and negative punishments, highlighted in table 2 (Makowska, 2018; Troisi, Mills, Wilkinson & Zulch, 2019).

Table 3.
Initial canine training

Initial canine training
Obedience tests to ensure that the canine operates safely and effectively according to mission requirements (with guided or unguided control exams and responsiveness to verbal commands);
Control tests, to ensure that the canine operates safely and effectively according to mission requirements (with guided or unguided control exams and responsiveness to verbal commands);
Training to perform a specific predetermined final response (active or passive alert) when locating the odor / trained odor;
Training should include exposing the canine team to a variety of locations, expected situations and searches;
The canine should be exposed to varying concentrations / amounts of available odor / aroma;
Exposure of the canine to a variety of different noise, sight and odor / odor distractors;
The canine must be trained to carry out a safe, effective and controlled search;
The training will be structured to meet the typical mission requirements of the canine team organization
Initial training of the canine team will continue until the required level of operational competence is achieved and the canine team is certified.

Note: Source: ANSI-ASB (2020) Author adjusted information in form of a table.

Dogs trained with positive reinforcement are more willing to look at their handlers during training than dogs trained with negative reinforcement, noting that those who are trained with positive reinforcement may simply be looking at the handler for the reward (Makowska, 2018). Furthermore, training with negative reinforcement, positive and negative punishment have been associated with less obedience and learning ability, compared to positive reinforcement (Royal Society for the Prevention of Cruelty to Animals, 2018).

It should be noted that the United States Department of Treasury (1993) has determined that variables such as class size and length of training are important factors in determining costs per dog in any training program. The same author reports that another variable that affects costs per dog is the number of students (that is, canine teams) per instructor; the student / instructor ratio for selected training programs is presented in (Table 4 and 5).

Table 4.
Ratio of canine teams to/instructor

Agency	Trained canine for			
	Patrol	Drugs	Explosives	Accelerants
U.S. Customs Services	n/a	6	n/a	n/a
U.S. Special Service	6	n/a	6	n/a
Military Working Dog Agency (JUSAF)	3	3	3	3
Connecticut State Police	3.7	3	3	1.7
United States Capital Police	6	6	6	n/a

n / a = Not applicable
Note: A canine team includes the handler and the canine
Department of the Treasury (1993)

Table 5.
Class size and duration of canine training programs for selected agencies

Class size and duration of dog training programs for selected agencies								
Agency	Class size: Average number of apprentices				Class duration: number of weeks			
	Patrol	Drugs	Explosives	Accelerants	Patrol	Drugs	Explosives	Accelerants
U.S. Customs Services	n/a	6	n/a	n/a	n/a	10	n/a	n/a
U.S. Secret Service	(b)	n/a	6	n/a	(b)	n/a	20	n/a
Military Working Dog Agency (JUSAF)	16	12	12	n/a	5	3	8.5	n/a
Connecticut State Police	11	6	6	5	14	6	6	7
U.S. Capital Police	6	6	6	n/a	14	10	12	n/a

n / a = Not applicable
Notes:
(a) All classes are for teams, which include a handler and a canine.
(b) All canines have cross training for patrolling and detecting explosives.
(c) Canines receive cross patrol training and one of two target scents: drugs or explosives.
Department of the Treasury (1993)

1.4.1 Canine detectors for human remains

The dogs that detect human remains are of the Canis familiaris species and are trained to find the smell of human decomposition and alert their handlers to its location. They are used in various forensic contexts, including the search and discovery of human corpses, anatomical pieces, or body fluids, and unlike hounds or other tracking dogs that locate a specific odor on the ground or on an object, corpse detection dogs are trained to detect the generic smell in the air, In particular, these dogs are conditioned to alert to the smell of human decomposition (Rebmann, David & Sorg, 2000; Dorriety, 2007) coming from surfaces, buried or under water (Sorg & David, 1998; Osterkamp, 2011; Binti-Sudar, 2015).

Other researchers (Rebmann et al, 2000), report that dogs are sensitive to the odor emitted by bodies that have a short period of decomposition and from bodies that may lack obvious signs of decomposition; these animals will also alert to decomposing bodies, skeletal remains, or even soils contaminated with human decomposition fluids. The same author highlights that due to the sensitivity of dogs' smell to determine specific odors in the air, even corpses buried for 20 years or more, can be detected in certain circumstances, just like objects that were once in contact with human remains. For dogs to perform optimally in detecting a target odor in highly variable and complex environments, they must be trained with a variety of odor mixes with and without the target odor. This is in contrast to a target odor-only training procedure, in which dogs are trained to detect the primary oxidant (the element/target) and not respond to "distractors" or odors without the target (Hall & Wynne, 2018). Therefore, the investigation of the factors that can influence the tendency of dogs to generalize and discriminate odor can inform training strategies to improve detection results (Moser, Bizo & Brown, 2019) (figure 7).

1.5 Odor source and training aids

The odor source for training of corpse-detecting canines has two origins: the first corresponds to synthetic products made in laboratories and the second source is human remains (Oesterhelweg et al., 2008; Dilkie & Veniot, 2017). The scent, associated with that of deceased people, such as the smell of dried blood, is considered human-specific, but its exact chemical composition is unknown. Odor analysis studies have been conducted on putrefying bodies, but the specific odor associated with recently deceased or "fresh" bodies has not been sufficiently investigated (Gill-King, 1997; Vass et al, 2002; Vass et al, 2004). Cadaver sniffing dogs not only point out when they find rotting human tissue or old blood debris, they also point out when they spot a recently deceased body (Vass, et al., 2004), noting that cadaver sniffing dogs do not give specific signs recognizing the smell of living people (Rebmann, David & Sorg, 2000).

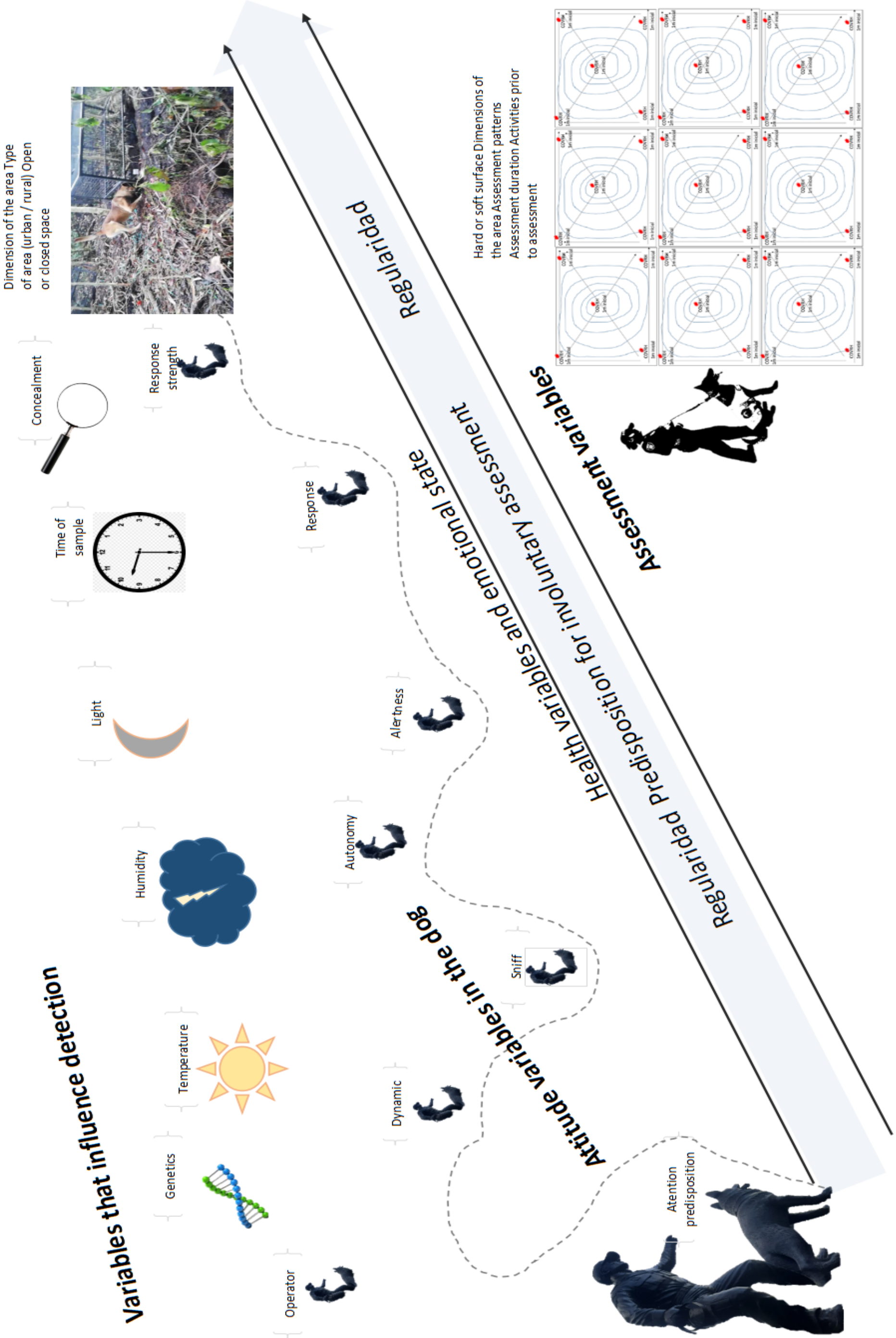
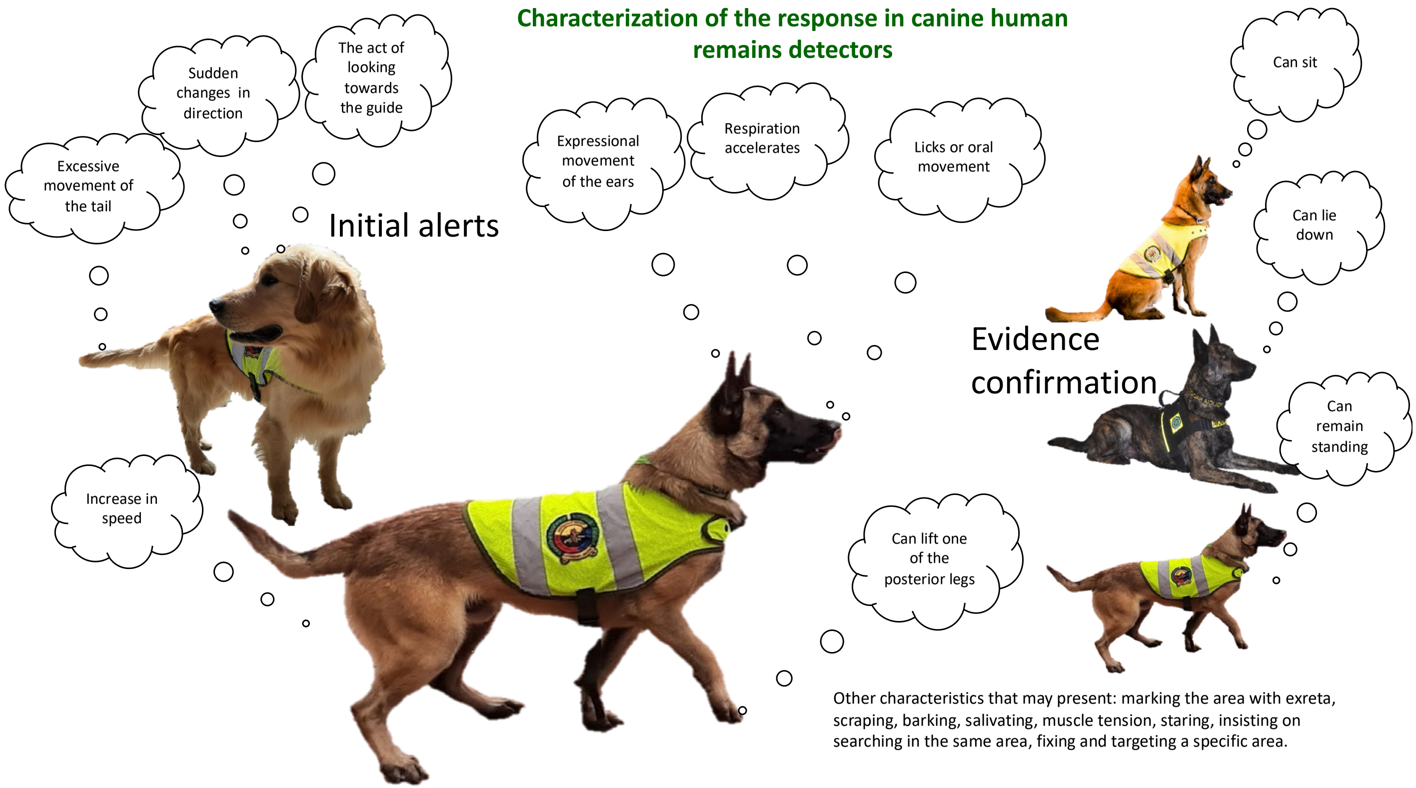


Figure 6.
Variables that influence detection, such as weather conditions, canine equipment status and geography.

Figure 7.
Characterization of the canine's response.



Note: The figure describes some of the physiological patterns that the canine human remains detectors can express when locating an odor.
Note: NPC

As a contribution to canine training, artificial flavors containing putrescence and cadaverine are commercially available, but these substances have not been established as the most relevant odor in the aroma of inert human tissue (Oesterhelweg et al, 2008). These substances are also present in all decomposing organic materials, as well as in organic materials from living individuals like saliva (Cooke, Leeves & White, 2003). So, the true "perfume of death" is discernible and its composition is important for a successful search by dogs (Oesterhelweg et al, 2008).

1.6 Recommendations for the acquisition, administration and final disposal of materials

1.6.1 Human remain odor source for canine training

When working with human remains for dog training, it is necessary to establish agreements with the Institute of Legal Medicine, research centers, among other entities authorized for the management of human remains that comply with all the requirements of the law. In the option of using synthetic substances for the training of canine detectors of human remains, there are recognized brands which provide these products; it is necessary to clarify that these products are pseudo-replicas and therefore do not replace the use of human remains within the process of guaranteeing effective dogs. Obtaining materials for the training of canine human remains detectors requires having good practices for the acquisition, administration, and final disposal of the materials. Therefore, the following recommendations are presented below.

1.7 Use of the ECDRH for forensic help

In Colombia, the search for corpses is carried out by criminal investigators, using a probe made of stainless steel, in order to verify the place where the corpse is possibly located. Unfortunately, judicial investigations are usually unsuccessful and uncertain as to whether the remains were in the place examined (Molina-Gallego, 2016, p. 3). Therefore, canine detectors of human remains are used within forensic sciences to investigate this type of crimes.

Morgan (2017) and Almazrouei, Dror & Morgan (2019) report that forensic science is a multidisciplinary field in which science, practice, law, and politics come together to support the legal process. Within this field, corpse-detecting dogs are valuable forensic aids in crime scene investigations, thanks to the fact that with proper training they can detect and locate with high sensitivity hidden human remains or their fluids while being easily managed (Riezzo et al, 2014). The well-trained detector dog is an excellent tool for crime scene investigation showing excellent sensitivity (75–100 %), specificity (91–100 %), and very high precision (92–100 %) (Oesterhelweg et al, 2008; Leitch Anderson, Kirkbride & Lennard, 2013). However, very little is known about the reliability of these animals in the detection of volatile compounds, since there are theories that mention the aging of aromas and the ability of the canine to detect these. Therefore, there are ongoing investigations on detectable corpse odor by canines due to prolonged time of onset (Dekeirsschieter et al, 2009). Many crimes include mutilation, dismemberment, disappearance, and concealment of bodies or skeletal remains of missing persons that wind up in rivers, seas, and cremation ovens (CNMH, 2018b). In Colombia, there is evidence of the execution of institutional investigations, financed by the Ministry of National Defense, which includes the Search and Rescue of People with Canines "Colombian Police Method" and Search for Human Bone Remains in Pit with Canines (NPC, 2008), working with canine pairs, supporting operational groups in search of corpses in mass graves, bone remains, or people (NPC, 2013). At the time of finding the corpse, the location, handling, and transfer of materials and bodies must be coordinated (Rodríguez, 2013).

The NPC selects, trains, and certifies canine teams to determine which dogs are suitable to start training and continue it, and to verify their subsequent performance. For this reason, in one of the studies carried out by the entity, 1.) The incidence of odor discrimination during training and final certification of canine substance detectors was measured and 2.) The correlation between odor discrimination, perseverance, and alertness during the "blind tests" were also measured. The results showed that the precision in isolating target odors was 99% (percentage of targets detected) with a specificity of 96% (percentage of targets correctly isolated), concluding that warning signs in real contexts, performing blind tests during the training and final certification, making pairings when exposed to noise and presence of people and other animals improve the canine teams' operational results (Prada-Tiedemann, Ochoa-Torres, Rojas-Guevara & Bohorquez, 2020). Under this model, canine police teams detecting substances in Colombia are certified and work correctly.

As a complement, one study determined, dogs' sensitivity to aged human decay fluid samples that were used as a training aid. The human decomposition liquid was collected and serially diluted to 1 part per trillion, two years later three police-accredited dog teams for the detection of dead bodies, under standard indoor training conditions, were tested to detect the odor and were able to detect the oldest and lowest dilution levels of decomposing liquid samples; this is used as a valid training aid for dogs that detect dead bodies (Buis et al, 2019). On the other hand, canines have shown to be able to detect human odors and identify them according to their characteristics, obeying the individual odor that each human being presents. Therefore, dogs continue to be used in forensic investigations to establish the relationship between objects and the odor of a suspected criminal (Vyplelová et al, 2014). This has turned canine certification tests into fundamental tools and guarantors of effectiveness for the exercise of odor discrimination and substance detection (Porritt et al, 2015).

According to Johnen et al. (2013) and Johnen et al. (2017), another factor to consider in the validation of training for the detection of human remains, is the number of dogs tested. In a report based on 14 studies, the average number of dogs per study was reported to be 4.6, ranging from 1 (n = 5) to 10 (n = 2) dogs. The usefulness of canines in detecting volatile organic compounds has a wide scope in operational activities carried out by both Colombia' armed forces and specialized rescue agencies; in the former, they can contribute to the discovery of crime-related odor particles, forced disappearances, and the discovery of materials involved in criminal events, among others, and in the case of rescue agencies, they allow for locating victims of massive disasters (Armstrong, Nizio, Perrault & Forbes, 2016). However, little is known about the variation between living human odor and postmortem human remains odor and the period of time during which one type of odor transits to the other (Armstrong, Nizio, Perrault & Forbes, 2016). Hence, it is essential to generate research that favors the generation of new scientific findings regarding odor molecules, variability over time and permanence and ability of the canine to detect them under different circumstances, including varied meteorological conditions.

1.7.1 Volatile Organic Compounds (VOC)

Janaway, Percival & Wilson (2009), Paczkowski & Schutz (2011) and Martin & Verheggen (2018), state that post mortem VOC emissions involve complex mechanisms of degradation of macromolecules. The human body is made up of approximately 64% water, 20% protein, 10% fat, 5% minerals and 1% carbohydrates. However, protein, lipid, and carbohydrate diversity, along with the relative abundance of these parameters, depends on many intrinsic factors (e.g., genetics, diet and weight, and micro biome), meaning that the origin of a cadaver's VOC depends on the macromolecules from which they originate. This is addressed in depth in the forensic discipline.

Forensic sciences have developed studies around volatile organic compounds (VOC), which are released by the decomposing carcass both in humans and animals and mainly in pigs (Paczkowski, Nicke, Ziegenhagen & Sch € utz, 2014), which are analogous to humans a total of 104 chemical compounds were identified and produced exclusively by the decomposition process, among which acids, cyclic hydrocarbons, oxygenated compounds, sulfur, and nitrogen compounds (Dekeirsschieter et al., 2009) were found. In another study, textiles associated with decomposing debris were evaluated for whether they retain and mimic the odor of aids used for training. The chemical odor profile of 100% cotton T-shirt samples was identified by collecting it from decomposing pig debris that was buried with garments. Throughout various stages of decomposition, pig carcasses were exhumed and cotton samples were obtained. The VOC profile of the textiles was collected by headspace solid phase microextraction (HS-SPME) and analyzed by two-dimensional integral gas chromatography-time-of-flight mass spectrometry (GC × GC TOFMS). Textiles were found to represent a useful aid to training, with a VOC profile reflecting a large subset of cadaveric rot odor (Nizio, Ueland, Stuart & Forbes, 2017).

Another study evaluated VOC in the first six months of decomposition of 6 human remains and 26 animals, finding 452 fully identified compounds. The same authors also presented a combination of 8 specific compounds for humans and pigs with the aim of determining if these compounds were released after 9 and 12 months, finding that 287 compounds were identified; furthermore, 9 new compounds were detected and 173 could not be determined (Rosier et al, 2016). Sulfur-containing compounds were less prevalent compared to the first month of decomposition. The appearance of nitrogen-containing compounds and alcohols was increasingly evident during the first 6 months and the same trend was observed in the following 6 months. Esters became less important after 6 months, while diethyl disulfide was only detected during the first months of decomposition. All 4 pig-specific and human specific esters, as well as pyridine, 3-methylthio-1 propanol and methyl (methylthio) ethyl disulfide were present after 9 and 12 months of decomposition. The 7 human-specific and pig-specific markers can be used as training aids for carcass-detecting dogs throughout the decomposition process and diethyl disulfide can be used in training aids during the first month of decomposition (Rosier et al, 2016).

Due to the afore mentioned, the NPC and "Texas Tech University" (TTU) carried out an investigation on how residual decomposition VOC change over time, as a function of the contact time between the decomposition substrate and the decomposition environment, monitoring the abundance of the vapors of the "objective odor" emanating from the soil from decaying human analogues (Sus scrofa) at different times. This analysis was carried out via SPME GC-MS for the identification of VOC and climatic conditions such as temperature and humidity, as well as the pH and humidity content of the soil matrix which was recorded showing how the residual decomposition odor changes during a period of time (Deruyter et al, 2020).

Related to the use of pigs in this type of research, Matuszewski et al. (2020) concludes that experiments using human carcass analogs (pig carcasses) are easier to replicate and more practical for controlling factors of confusion than studies based solely on humans and are therefore likely to be our main epistemic source of forensic knowledge for the immediate future. Furthermore, due to ethical restrictions, dogs are not trained with human corpses but with pseudo-odors or human tissues, such as blood and decomposition fluid (Buis, 2016). In the province of Nova Scotia, human remains were donated through the procurement program at the Nova Scotia Medical Examiners Service and were introduced to the training of human remains detectors for testing with boxes and field searches; being classified according to the concealment method: 1.) above the surface, 2.) underwater, 3.) buried or hanging; they were tested under various climatic conditions, search terrains, and decomposition stages, with a training success rate of 94% (Dilkie & Veniot, 2017).

1.8 VOC analysis with gas chromatography and mass spectrophotometry

Biological olfactory systems have the extraordinary ability to not only detect various volatile compounds (odors), but also to distinguish between them (Furton, Caraballo, Cerreta & Holness, 2015). Therefore, studies have used technology to help identify what type of odor molecules these systems detect and within these elements, ion mobility spectrometry (IMS) has been the most used analytical instrument to detect forensic traces. Therefore, the use of these techniques for the correlational analysis of volatile organic compounds detected by canines in criminal scenarios gives reliability to the execution of work in the detection of binomials, although there are other techniques such as interconnected thermal desorption with gas chromatography and mass spectrometry (TDS-GC-MS) (Dekeirsschieter et al, 2009), which can contribute positively to the analysis of samples for detection of volatile organic compounds in soil contaminated by cadavers.

Another technique called gas chromatography (GC) coupled with mass spectrometry (MS) is the tool of choice for analysis of VOC produced during decomposition processes. Solid phase extraction (SPE), solid phase micro extraction (SPME), and thermal desorption (TD) have been used for sample collection and transfer to GC-MS (Brasseur et al, 2012); integral two-dimensional gas chromatography together with time-of-flight mass spectrometry (GC×GC-TOFMS), is a suitable tool for the determination of volatile organic compounds (VOC) emitted during the cadaveric decomposition process (Dubois et al, 2019).

Temporary changes in VOC patterns during the decomposition process of various human tissues were measured from tissue samples of five different cadavers that were regularly sampled by dynamic pumping in sorbent tubes and thermally processed in a GC×GC-TOFMS system, reaching an n of 774 data. It was also shown that there were subtle differences between the sets of compounds produced from each organ due to the different functions they carry out within the human body. However, the VOC profiles were more similar between the organs of the same corpse than when comparing samples from different corpses and it could be pointed out that different circumstances can cause variations between the corpses analyzed: from the individual’s diet and lifestyle to the moment of death (Dubois et al, 2019).

In a comparative study, Raymer, Rojas-Guevara & Prada-Tiedemann (2020) studied VOC from soil decomposition of human analogues (Sus scrofa), locating meat and carcass samples outdoors to model the putrefaction process and collecting VOC intermittently for a month. The anatomical pieces were left to decompose for 14, 17, and 21 days, and the soil samples were taken once a week for a month. Instrumental analysis used solid phase micro extraction fibers (SPME) coated with divinylbenzene / carbon / polydimethylsiloxane (DVB / CAR / PDMS that were injected into a gas chromatographic mass spectrometry (GC-MS) system for identification of the odor profiles of the extracted soil. VOC of interest were identified over the duration of the experiment, showing distinctive trends in compound abundance and disappearance.

Another study measured the change in the VOC odor profile of decomposing human analogues during the first 72 hours' postmortem (Armstrong, Nizio, Perrault & Forbes, 2016). In the previous investigation, three pig carcasses (Sus scrofa) were used on a soil surface and left to decompose in natural conditions. Decomposition odor was frequently sampled for up to 75 hours after death and analyzed by two-dimensional integral gas chromatography and time-of-flight mass spectrometry, identifying a total of 105 VOC during the early postmortem period. The VOC profile was very dynamic during the initial postmortem period, changing both hourly and per day, with a transition period after 43 hours' postmortem, where the VOC seemed to change from a different ante mortem odor to a more widespread postmortem odor.

When investigating burning bodies and according to the influence of combustion on the VOC measurement, it was determined that both in the absence and presence of the "gasoline" accelerator, no influence on the general odor of decomposition was made, noting that on day 1 after ignition of pig carcasses, the products of combustion and pyrolysis dominated the odor profile of the anatomical parts in which gasoline was used. However, the products of combustion decreased over time and the presence of gasoline was completely lost on day 9 (Nizio & Forbes, 2018). A total of 18 postmortem VOC were tentatively identified to differentiate burned control pig carcasses throughout the test period. However, it is important that odor detector dogs are exposed to training aids that reproduce their target odor as accurately as possible, using incinerated training aids when possible (and necessary) (Nizio & Forbes, 2018).

A comparison of human and porcine decomposition rates and odor profiles was performed in an Australian setting, using four human carcasses and four pig carcasses that were placed in an outdoor environment and over two seasons, analyzing VOC by two-dimensional gas analysis chromatography and time-of-flight mass spectrometry. According to the visual observation, there were differences in the decomposition rates between the anatomical pieces and there were variations of VOC over time, concluding that the decomposition and the VOC profile of the remains of pigs and humans were different. However, under colder conditions, the results for each species became more comparable, especially during the early stages of decomposition (Knobel, Ueland, Nizio, Patel & Forbes, 2019). In a study that analyzed the odor profiles of human carcasses over several seasons in Australia, human remains detection dogs for and GC × GC-TOFMS were used for five trials conducted throughout the fall, winter, and spring. The analysis showed differentiation between compounds and classes of compounds produced by each donor and revealed that the cadavers placed during the warmer climate showed greater variety and abundance of compounds than the cadavers placed during the colder climate, without identifying consistent recurring compounds (Deo, Forbes, Stuart & Ueland, 2019).

1.9 Correlational studies between ECDRH and volatile organic compounds.

Whenever a crime is committed, forensic personnel are asked to collect all kinds of evidence to establish the relationship between the suspects and the crime (UNODC, 2009). When any evidence is accidentally destroyed or not found, there is a type of latent evidence that is always deposited at the crime scene: a unique human smell. Recently, the use of trained canines to selectively detect human odor at the crime scene has increased (Breed & Moore, 2015). To consolidate this type of evidence, it is essential to have an exact knowledge and awareness of the chemical signature of volatile compounds that could indicate the presence of the alleged offender at the crime scene (Filetti et al, 2019).

In one study, VOC released by subjects handling different items were detected to imprint their odor. After handling, each item was wrapped in VOC-free sterile cotton gauze for 48 hours for secondary transfer. VOC were detected by HS / SPME-GC / MS and with dogs at different times (up to 15 days). The dogs isolated the individual who manipulated the object at the crime scene. Dog training showed sensitivity between 99.48 and 100% and specificity between 60 and 100%, with a positive predictive value (PPV) between 97.94 and 100% and a negative predictive value (NPV) between 85.71 and 100% (Filetti et al, 2019). On the other hand, a variety of forensic disciplines could benefit from specific human markers (VOC), mainly in the search for human bodies or remains due to the olfactory capacity of cadaver detection dogs (Rosier et al, 2015). Canines have the ability to detect odor particles in human remains, even when the structure and composition of the soil in which the body is found varies, and this is done with an accuracy ranging from 75% to 100%, up to 667 days after the body's extraction from the soil surface, indicating a significantly high olfactory capacity. However, the substances detectable by canines when there are no cadaveric structures or traces of organic matter compatible with human remains are still unknown (Alexander, Hodges, Bytheway & Aitkenhead-Peterson, 2015).

Irish et al. (2019) mentions that human remains detection dogs are routinely used internationally by police and civilian search organizations to locate human remains in land and water, but that little is currently known about VOC that are released underwater by corpses, or how this compares with those emitted by a corpse deposited on the ground, and ultimately, how this affects the ability of dogs to detect drowned victims. For this reason, solid- phase microextraction gas chromatography mass spectrometry was used to identify the VOC released by porcine carcasses (Sus scrofa domesticus) on the surface and submerged in water, to determine if there were notable differences in decomposing odor depending on the location and to mitigate the possibility of human remains being lost operationally.

1.10 Public policy and regulatory framework

The second title of the Colombian Political Constitution describes the fundamental rights, guarantees and duties with respect to Judgment C-317/02 and article 12 that states that no citizen will be subjected to forced disappearance or other inhumane treatment (Constitutional Court of the Republic of Colombia, 2002). In addition, Law 589 of 2000, states: “through which genocide, forced disappearance, forced displacement and torture are characterized; and other provisions are issued”. Through this, the Code of Criminal Procedure was modified to include genocide, forced disappearance, forced displacement and torture as crimes and to develop pecuniary sanctions and corresponding deprivation of liberty (Minjusticia, 2000). The confirmation of the National Commission for the Search of Missing Persons (CNBPD), in charge of the design, evaluation and support of the execution of the search plans is also filed (CNBPD, 2012).

The National Registry of Disappeared Persons (RND) reports information that includes: “identification of the disappeared persons, place and date of the artifacts, exhumed or inhumed remains of unidentified persons and information of the place and date of the discovery, conditions, characteristics, evidence, results of technical, scientific or testimonial studies and any data leading to its identification”, which is stored in the Information System of the Network of Disappeared Persons and Corpses (SIRDEC) (Colombian Congress , 2000. Article 9), which is in charge of the National Institute of Legal Medicine and Forensic Sciences” (CNBPD, 2012). With the elements above, Colombian regulations are obliged to take the necessary steps to establish the whereabouts of the victim, have knowledge of the reasons for their disappearance, notify their relatives of this and establish the Urgent Search Mechanism (MBU), which is used as a tool to locate people who are presumed to be missing and, so the judicial authorities immediately order all the necessary procedures for their location (Attorney General’s Office, 2017).

Within this regulatory framework, the tools to search for people do not include the use of certified canine teams, although the PNC and the Colombian Army use canines for the detection of narcotics, explosives, wildlife and paper money, among others, corroborating the efficacy of the canine guide service in aiding different criminal activities in the country. In another way, to provide standardization of terms and definitions used in the detection dog community and to promote the use of standardized terminology with consistency across jurisdictions and to ease the judicial system of terms and definitions in conflict, a technical document was produced by the Academy

Standard Board (ASB-AAFS, 2017) and the American National Standards Institute and the ASB to develop general guidelines for training, certification and documentation of canine detection disciplines (ANSI-ASB, 2020).

Finally, the development of a procedure to locate clandestine human remains is an important effort for the field of forensic science. However, the human remains detection dog training protocol (HRD) varies between different countries, agencies and individual teams of dogs and handlers (figure 8). Training methods must be consolidated for their implementation, taking into account political legislation and the participation of agencies to apply successful methodologies while maintaining regulations. The basis of HRD dog training can be standardized and advanced training can be adapted to regional conditions involving environment, climate and terrain search variables (Dilkie & Veriot, 2017).

1.11 Obtaining anatomical cadaveric pig pieces

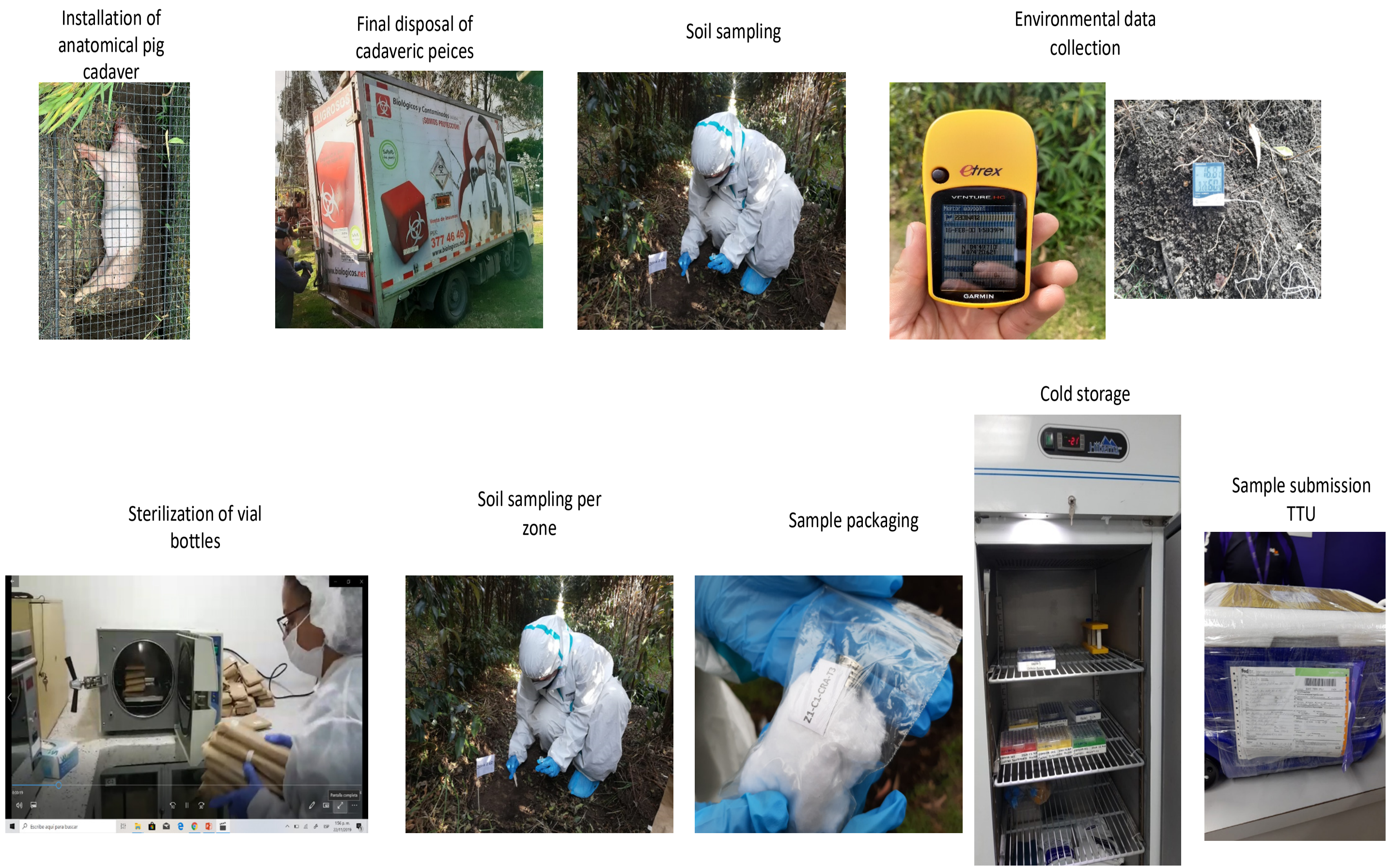
Most decomposition studies in forensic entomology and taphonomy have used non-human corpses. Following the recommendation to use carcasses of domestic pigs as analogues for humans in forensic entomology in the 1980s, pigs became the most widely used model carcasses in forensic science (Matuszewski et al, 2020). Experiments using human carcass analogues (pig carcasses) are easier to replicate and more practical to control for error factors than studies based solely on humans and are, therefore, likely to remain the main epistemic source of forensic knowledge for the immediate future (Matuszewski et al, 2020).

In this project, 12 Landrace pigs were used as analogues for the smell of human decomposition; the pigs will be purchased from a certified farm by the Colombian Agricultural Institute (ICA), located in the savannah of Bogotá, and delivered to researchers. The pigs were 4 months old, of both sexes and without previous management by the members of the project while they are alive. The ethics committee of the National Directorate of Schools determined the obtaining of the pigs, by means of a letter that indicated the purpose of the investigation and how they were used.

1.11.1 Design of the experiment

The pigs (n = 12) were organized within the facilities of the National School of Carabineros, owned by the NPC, establishing different points between samples and under uncontrolled climatic conditions. These specimens were located with an adjoining control area of three meters and will be covered with a strong and fine chain-link mesh, to prevent external animals from affecting the scene. In addition, a control point will be established, where no pig will be located, but the volatile organic compounds (VOC)

Figure 8.
Field study in the tropical cold climate of the municipality of Facatativá, Cundinamarca.



Note: NPC.

present in the soil will be measured (baseline), to avoid errors between decomposition results. The pigs were placed on their lateral ulna, directly on the ground, in a flat area, obtaining the respective permit at the different location sites. Each pig and the control were protected with small wire mesh cages that surrounded it to avoid sweeping the carcasses. No human had access to the corpses in the assigned areas, only the researchers of the project, determining the established roles. The first group of pigs was left exposed for 24 hours, the second group for 48 hours, the third group 72 hours, and the fourth group 90 days (Figure 9). After the exposure time was reached, the pig carcasses were properly removed. A soil sample was taken at the time of initial extraction and once a week for a period of six months (Figure 10).

1.11.2 Sample preparation and collection of decomposition odor

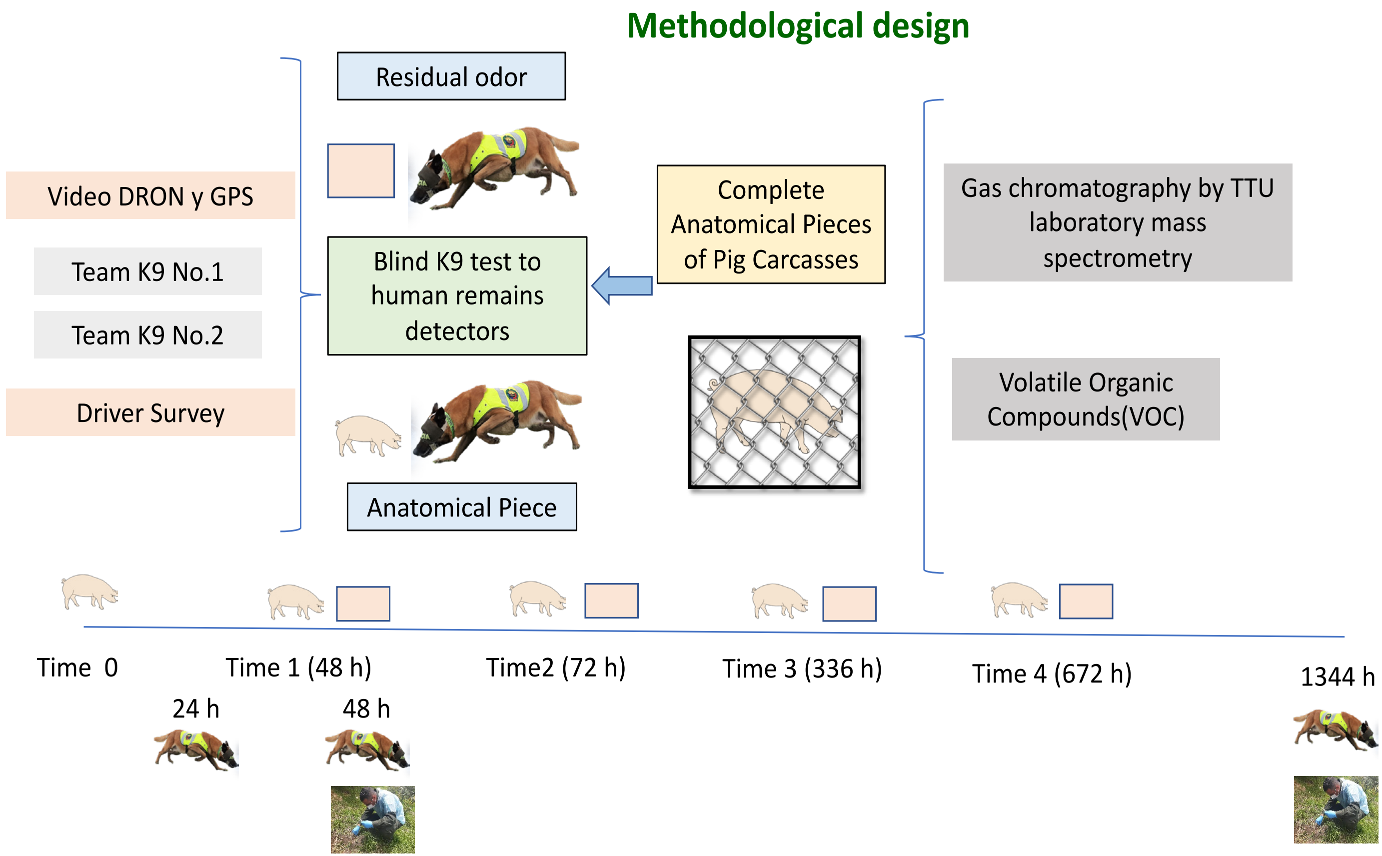
After removal of the carcasses, approximately 5 grams of soil were collected with a sterile spatula from each site and placed in 10 ml glass vials. All sample-collection glass vials were sterilized prior to use, using a methanol solvent and a baking time of 36 hours at 105 ° C, as this cooking process has been shown to help remove remaining VOC (Cablk, Szelagowski & Sagebiel, 2012). After placing the soil sample in a 10 ml glass vial, it equilibrated for a minimum of 24 hours before packaging and storage was performed. The sampling process was completed in triplicate for all sample locations where pigs were placed and in the control area (figure 11). These samples in triplicate were taken below the torso region of the body, due to it being an abundant area for decomposition, since the organs are located in the center and where most of the liquid accumulates for adipose tissue pressure (figure 12).

Each soil sample was collected in a straight line, with approximately 10 cm between each point. (Figure 13) The soil was sampled at no more than 7 cm depth. The sample areas were flagged once the housings were removed to ensure that samples were taken from the correct areas each time. (Figure 14) Climatic conditions such as temperature, rainfall, and humidity were measured weekly during each sample collection. This helped determine if weather conditions played a role in VOC abundance (Figure 15).

1.11.3 Registration and detection by binomials

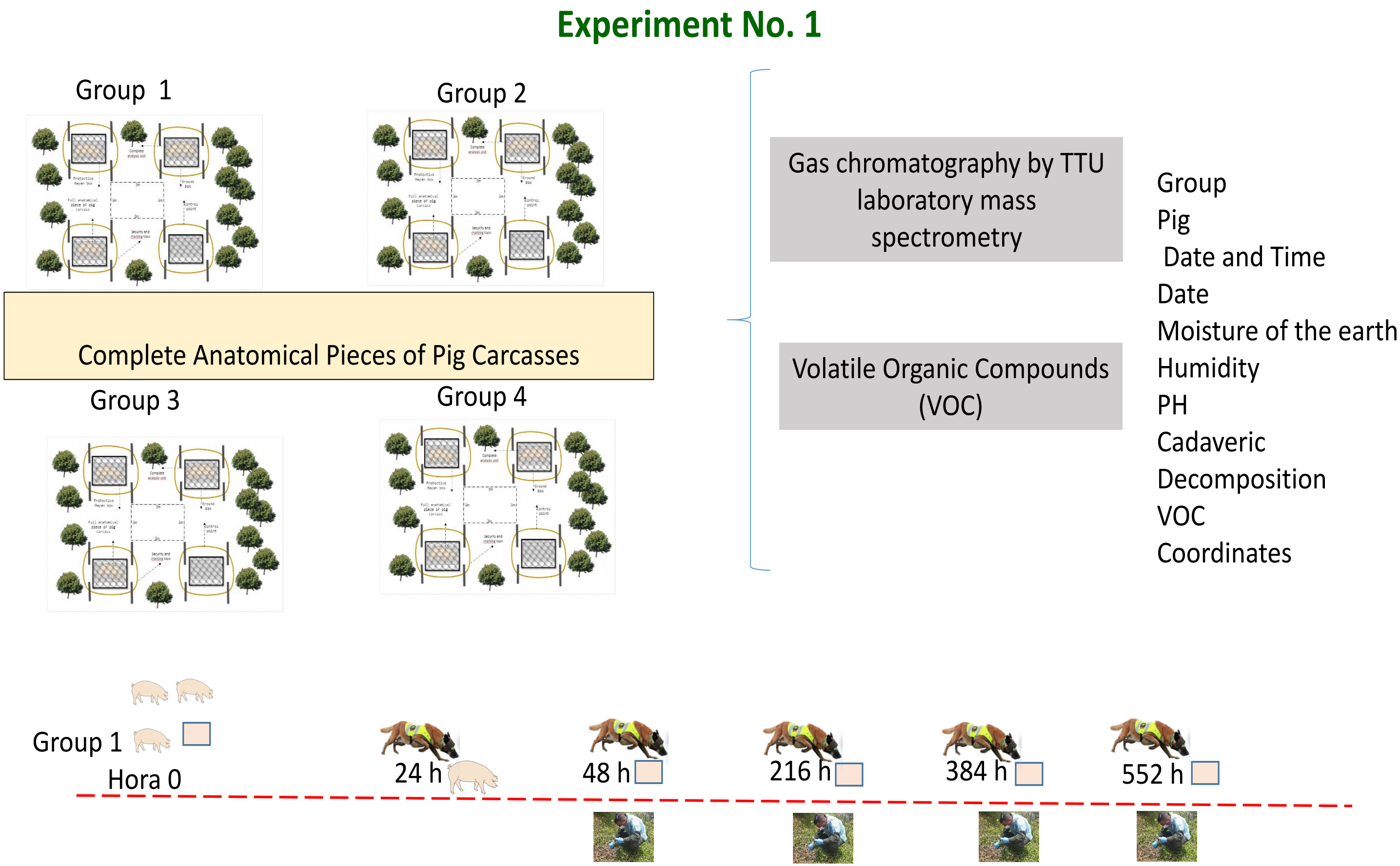
Two certified dogs were used in the detection of human remains, which were certified by the canine technical evaluation committee of the School for Canine Guidance and Training, according to the protocols established by the institution. A blind test was performed on each pair, 24 hours after the carcass was exposed, and the 12 samples were evaluated (n = 12 pigs). This evaluation of the residual odor by the canine will continue each week until a positive alert is no longer given, in addition to monitoring the temperature and humidity of the land, taking note of atmospheric data each day, and a decomposition sequence per week along with forensic photography (figure 16).

Figure 9.
Methodological process: Use of canines and sampling for VOC measurement.



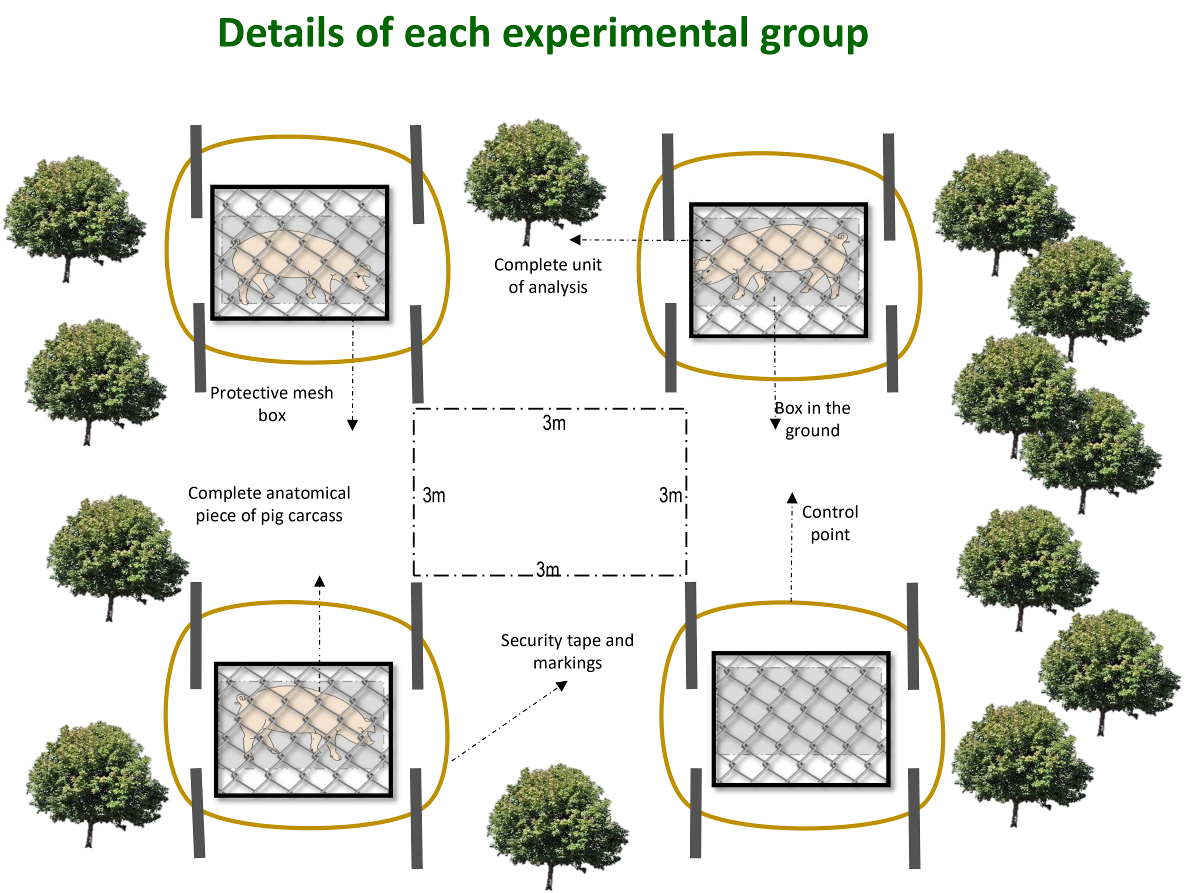
Note: NPC

Figure 10.
Experiment one.



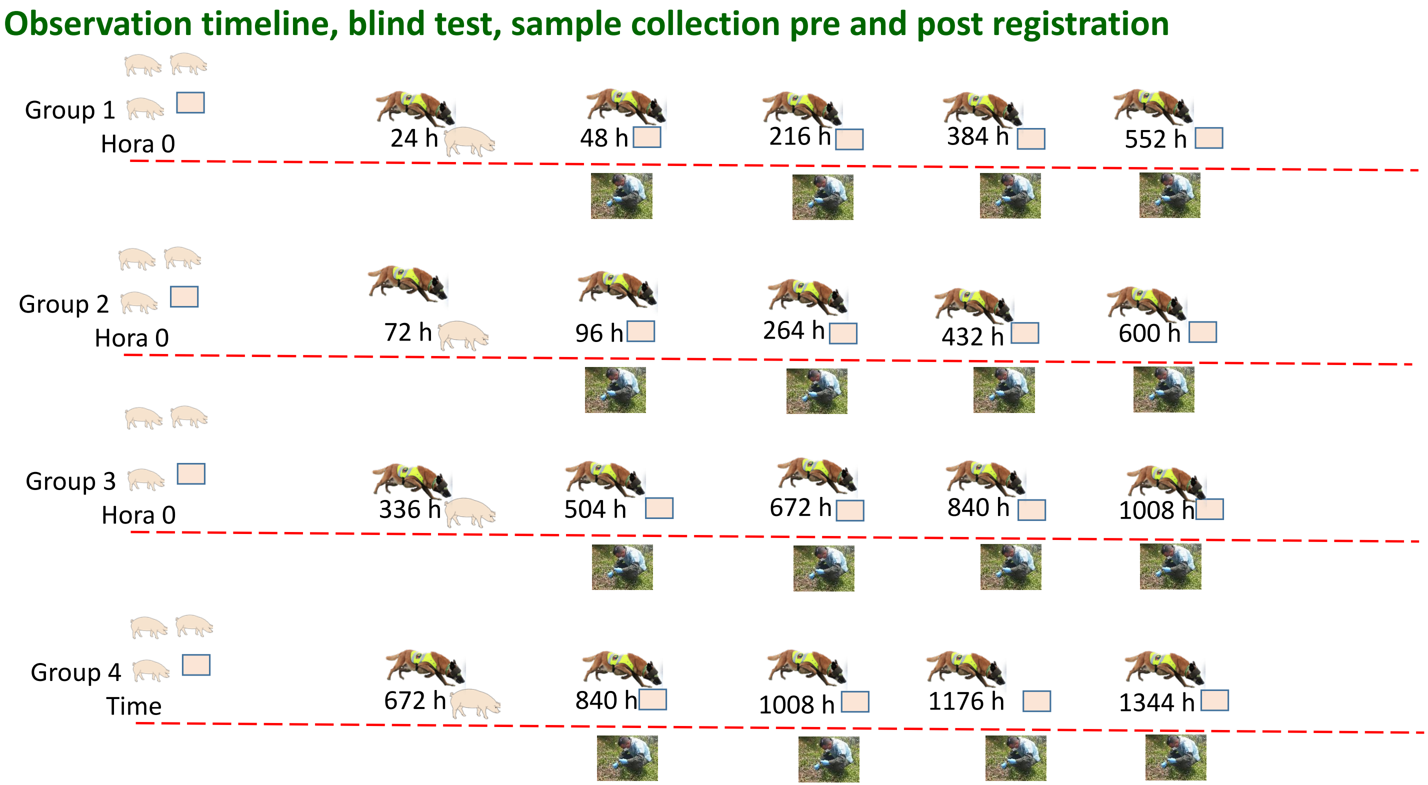
Note: NPC

Figure 11.
Details of each experimental group.



Note: NPC

Figure 12.
Observation timeline, blind test, sample collection pre and post registration.



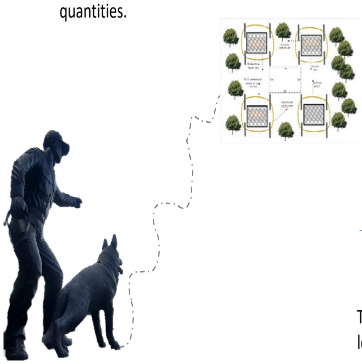
Note: NPC

Figure 13.
Technical training sequence.

Technical sequence for learning trace patterns in the VOC registry of human remains

Sample preparation

Primary odor source VOC impregnated in gauze or cotton. VOC Contained in sterilized steel container.
Secondary odor source impregnation of real scenarios with VOC of human remains in varying quantities.



Stimulus 1	**Response**
VOC sterile steel flask, Soft caress, plus search word	Explore, sniff and stay in the area where the VOC is located

Vary scenarios, temperature, amount of light among others

The exercise is repeated as many times as necessary or as much as the canine allows until learning is achieved.

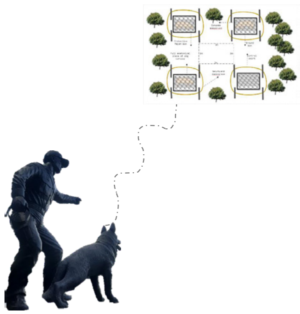
Note: NPC

Figure 14.
Technical training sequence.

Technical sequence for learning trace patterns in the VOC registry of human remains

Sample preparation

Primary odor source VOC impregnated in gauze or cotton VOC contained in sterilized steel container.
Secondary odor source VOC impregnated in a sterile mat placed on the floor and fixed.



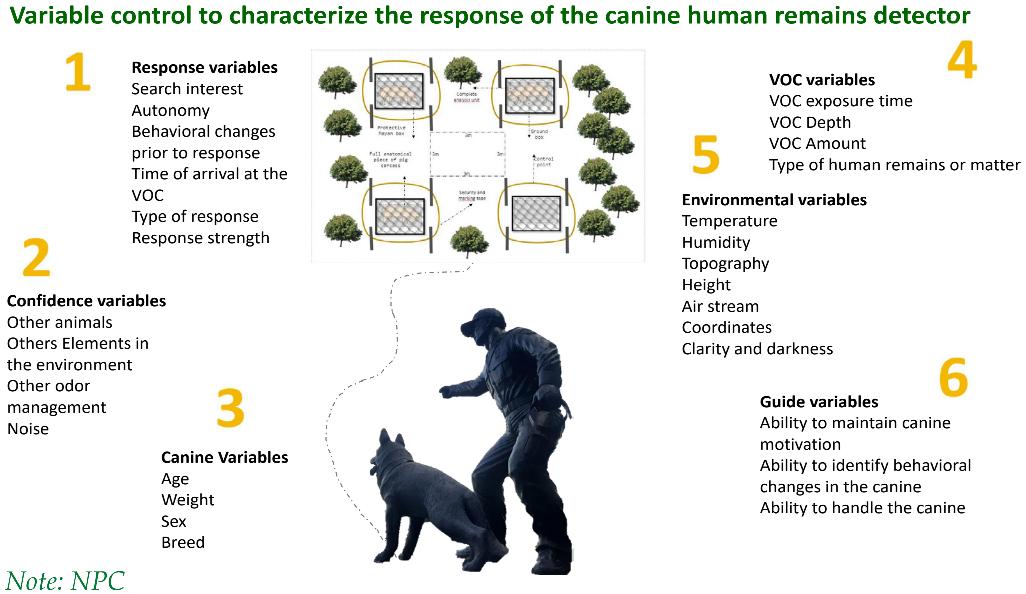
Stimulus	**Reinforcement**	**Response**
VOC sterile steel flask	Food or teether, more soft caress, plus word of confirmation	Explore and sniff the steel flask with the VOC
Stimulus 1	**Stimulus 2**	**Response**
VOC sterile steel flask, Soft caress, plus search word	Mat with VOC	Explore and sniff the mat with the VOC
Stimulus 1	**Stimulus 2**	**Response**
VOC sterile steel flask, Soft caress, plus search word	Mat with VOC	Explore, sniff and stay on the mat with the VOC

Vary scenarios, temperature, amount of light among others

The exercise is repeated as many times as necessary or as long as the canine allows until learning is achieved.

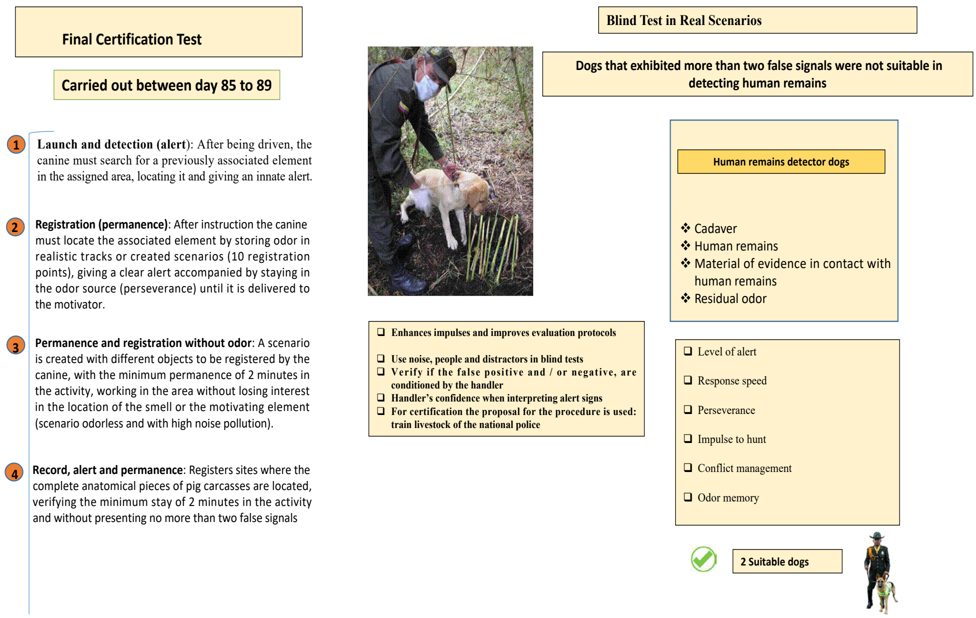
Note: NPC

Figure 15.
Control of variables



Note: NPC

Figure 16
Certification test.

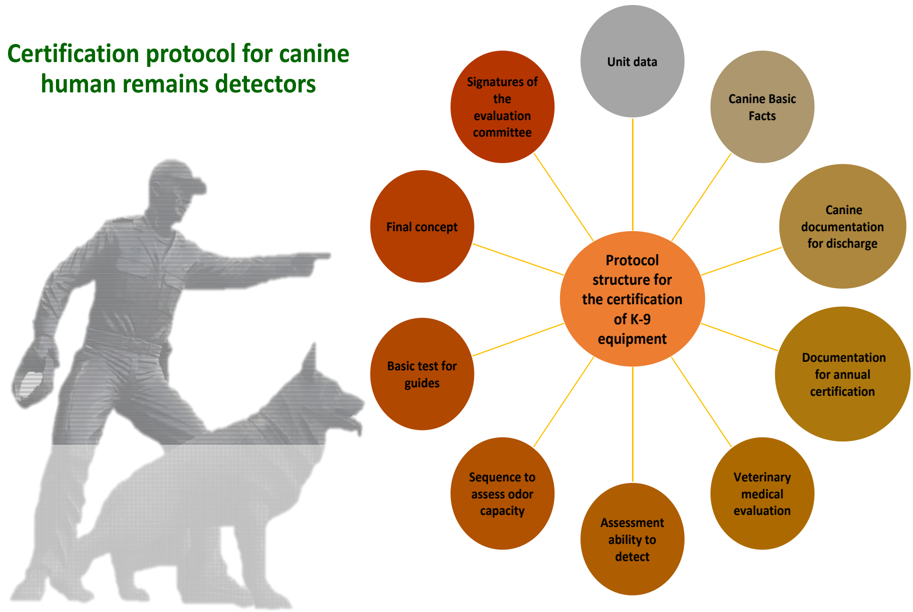


Note: NPC

1.12 Results and discussion

In this chapter, the Canine Human Remains Detection Teams (ECDRH) were trained to alert about the odors emanating from a body that is analogous to the human decomposition odor (sus scrofa). In addition, after the pig's anatomical pieces were removed from the original site, a response alerting the presence of the remnant odor was issued, subsequently validating the findings with the human bones experiment proposed (figure 17). Likewise, it was determined that six months after the anatomical pieces of pig corpses were removed, the canines presented an alert in the place where the carcass existed. These results are consistent with the Forbes (2017) studies, where dogs had the ability to detect in areas where bodies had previously been decomposing and were no longer present, known as residual odor.

Figure 17.
Canine human remains detection team certification protocol



Note: NPC

Rebmann, David & Sorg (2000) carried out scientific work that involved canines specially trained to find the human odor and issue an alert to be identified by their handler, commonly known under the term: "search for death" (Van Denhouwe & Schotsmans, 2014), also, studies were done involving the aroma of human analogues such as pork and carcasses (sus scrofa) and volatile organic compounds (VOC) involved in the residual odor, which established that the amount of time in which decomposing tissue comes into contact with soil directly affects the amount of VOC detected (Raymer, Rojas-Guevara & Prada-Tiedemann, 2020), which is similar to the period of exposure and soil contact of cadaveric pieces found in the results of this research.

Residual odor can be defined as: “the odor that originates from a target substance, which may or may not be physically recoverable or detectable by other means” (Furton, Greb & Holness, 2010). According to the ECDRH, there are few investigations that support the effectiveness of dogs, especially in scenarios where there is or were material evidence in crimes such as homicide, forced disappearance, and other associated threats such as rape (Rojas-Guevara, Córdoba- Parra, Bohórquez, Vega-Contreras & Tiedemann, 2021. in press). Furthermore, in open field crime scenes, corpse or blood detection dogs can locate samples after days, weeks or months, but have difficulty finding samples on wooden surfaces after a month and on concrete after a week (Chilcote, Rust, Nizio & Forbes, 2018). These figures are dissimilar to the results found in this study, possibly due to the type of surface and the action of water or elements used to “erase” this type of biological waste.

1.12.1 Experiment 1 Results

In this chapter, the dog’s response and its understanding facilitated by the handler and two evaluators (the first evaluator in the field and the second an aerial device that records the search process of the canine team) are presented. The results indicate that the proposed protocol (figure 18) should be modified with small changes, according to the type of terrain (dense vegetation, open area or difficult-to-access terrain). Alliances should be made with the institute of legal medicine and forensic sciences to propose short-term protocols for the use of human corpses or their parts, in order to further standardize these types of studies and possibly incorporate human corpse farms for future multidisciplinary studies.

The two ECDRH show that, according to the standards established by the institution, during the search, the dogs were more effective in clear field areas or with little vegetation (zones 1 and 2) (figure 19A), allowing them to maintain a continuous registration pattern during testing. On the contrary, in areas with very dense vegetation (zones 3 and 4) (figure 19B), the canines had difficulties reaching targeted areas. It is important to remember that the operational work is a synergy between the guide and his dog. The difficulty approaching these sites existed due to the abundant vegetation and lack of access routes, resulting in the dog leaning too much on its handler. These findings mean that it is essential to work on two components: the first is to search for a breed that executes a systematic search by barking or marking the site and likewise including more demanding test selections. Also, during dog training, there must be autonomy while performing the registration and teaching the dog to present signals, such as those shown, where when evidence related to the object is detected, the signal is easy for the handler to understand.

Figure 18.
Sites where the anatomical pieces of pig carcasses were located.

Figure 19.
Location scenario variants

According to the results of this study, where Global Positioning System (GPS) and unmanned aerial vehicles were used; monitoring was also difficult because of the use of leashes, collars, or harnesses, where the geolocation technological device was anchored, therefore; monitoring was problematic due to cramming between vegetation. The second methodological option to follow during the registration with canine detectors of human remains in areas with dense vegetation is to make the most of their capacity by not wasting their energy in searches within an extensive scenario, where good results will probably not be obtained. Therefore, it is necessary to delimit the area where the canine will perform the search, especially in cases where there are missing persons requiring more detailed framing of search areas to increase the possibilities of making a positive finding. Said proposal, lies in having more accurate information about the possible place where the victim was, implying a technical training process, where the canine must remain calm to maximize its ability to trace and focus on locating the scent cone in order to arrive quickly to the target.

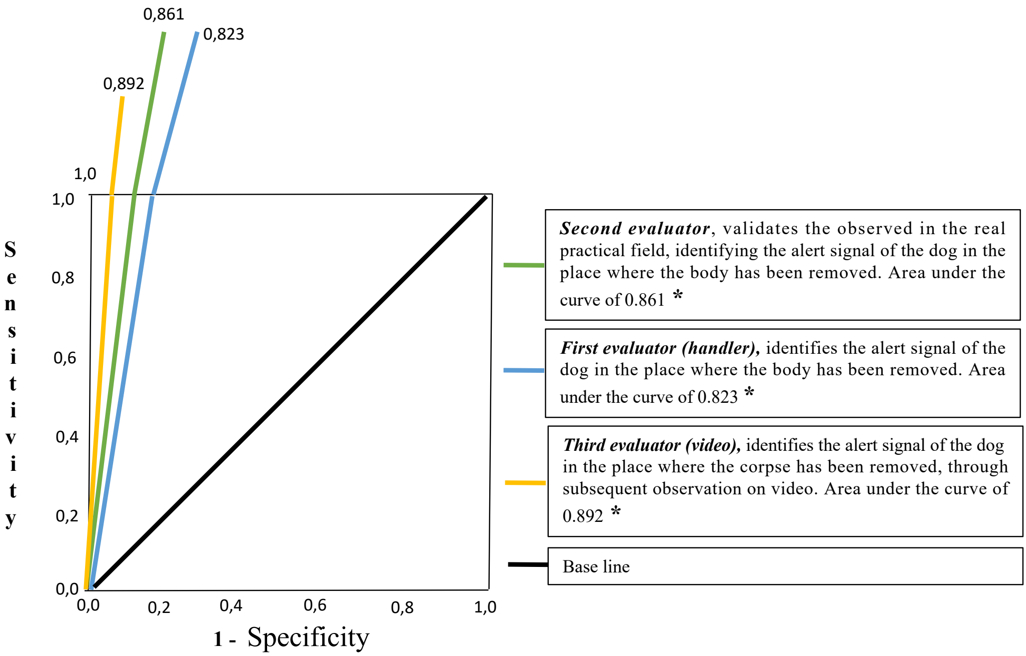
Canines must learn to identify bodies in different stages of decomposition: fresh, early putrefaction, advanced or skeletal and adapt to these aromas so they can be validated with the VOC present and in order to obtain evidence that allows research to be directed at that level. This implies planning the terrain approach to achieving better results, covering a greater amount of terrain. The predictive validity of this study has forensic relevance from the field of taxonomy, being useful as a starting point in the near future to help solve forensic cases or make contributions to the criminal investigation by continuing to adjust protocols such as the one proposed.

Likewise, more multidisciplinary studies are necessary, involving foundations or associations that employ forensic farms: allowing the use of human bodies in different phases of their decomposition, climates, terrains and contexts. The data obtained are more difficult to interpret, because they do not lend themselves easily to making predictions since they are experiments under uncontrolled environmental conditions and the responses of canines and their handlers are affected by various factors. In the near future, they will have profound implications in practical applications, being necessary in the dynamics of the study of human odor. To finalize this part of the results, it is necessary to establish agreements between research centers or entities authorized by law, in order to standardize and achieve a better administration of this type of biological aids to train, certify and obtain more efficient dogs and with procedures adjusted to the existing regulations, under bioethical principles and that tend to improve the aspects of biosafety.

Sites where the anatomical pieces of pig carcasses were located. Zone 1 and 2 of figure A are sites with little vegetation, where the finding was more efficient. Figure B, determines zones 3 and 4, as sites with more complex approaches due to dense vegetation.

There are canine blood detectors, which are used to locate evidence at crime scenes where there is no corpse, employing searches after long periods of time for when the homicide or disappearance occurred (Rust, Nizio, Wand & Forbes, 2018), generating important contributions such as that observed in this study, which standardizes the protocols and double-blind tests for ECDRH. The previous results are similar to those found by Alexander, Hodges, Bytheway & Aitkenhead-Peterson (2015), which verified that the canines detected the residual odor of corpses after 667 days of the removal of the body, presenting an accuracy of 85.7%. Particularly at this project, the cadaveric anatomical pieces of the pigs were influenced by the variation and height above sea level (2700m approx.), topography, vegetation, access to the stage, amount of sunlight, which can be evidenced in figure 19).

Figure 20.
Double-blind test results without bodies.

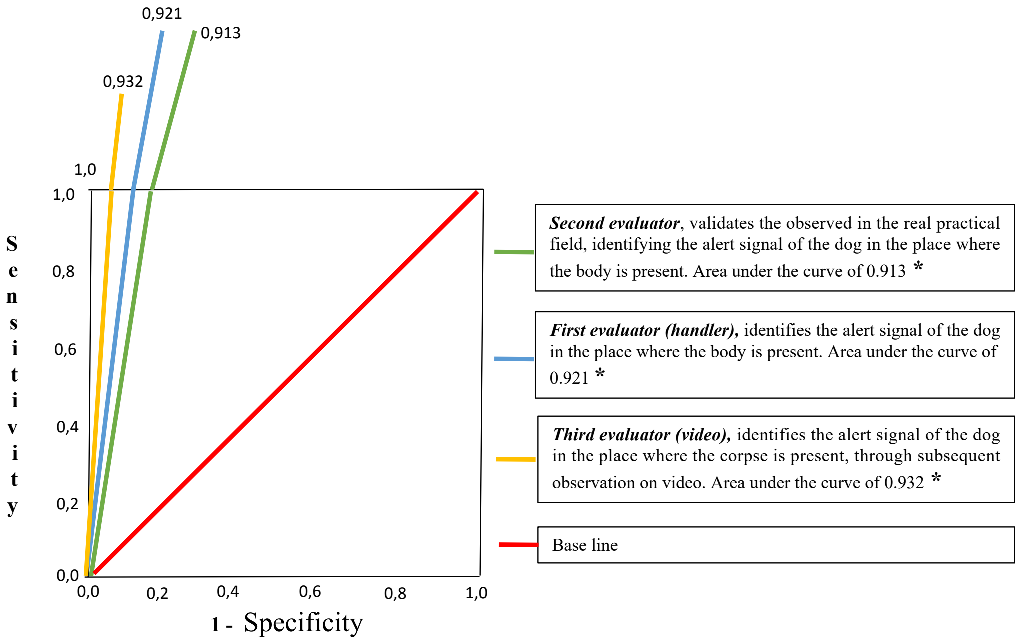


* *Average level of agreement in each of the three evaluators, in the 3 groups, at the different times in the different places where the body has been removed (between 24 hours and 1344 hours).*

1.12.1.1 Sensitivity and specificity of the response of the canine team when removing the body

In this research, 86% reliability is observed among the double-blind tests performed without a corpse, with an almost perfect level of agreement between the first evaluator (handler), who interprets the alert of his canine when he arrives at the site where the body was removed, by raising one of his hands (indicating a behavioral change in the canine), that the dog's response is positive; the second evaluator was an experienced instructor, who validated the dog's response when raising one of his hands (explained beforehand to do so, if he observed a behavioral change in the dog), indicating the change in behavior of the canine team; the third evaluator certified the information by verifying the response signals of the handler and the second evaluator, by observing the video (figure 21). It should be noted that the handlers and the first evaluator did not know the place where the bodies were found and they did not know if they had been removed or were in different places.

Figure 21.
Canine response to pig carcasses.



* *Average level of agreement in each of the three evaluators, in the 3 groups, at different times, in the different places where the corpse is found (between 24 hours and 662 hours).*

Sensitivity and specificity of the double-blind corpse-free test, plotted using Receiving Operating curves. An 86% reliability is observed, with an almost perfect level of agreement between the three evaluators: 1) first evaluator (handler): identifies the alert signal of the dog in the place where the body has been removed. Area under the curve of 0.823 (Cohen's Kappa of 0.823), 2) second evaluator: validates the observed in the real practical field, identifying the alert signal of the dog in the place where the body has been removed (Cohen's Kappa of 0.861) and 3) third evaluator (video): identifies the alert signal of the dog in the place where the corpse has been removed, through subsequent observation on video. (Cohen's Kappa of 0.892).

1.12.1.2 Sensitivity and specificity of the response of the canine team with the anatomical parts of pig carcasses

In this research, 92.4% reliability is observed between the double-blind tests carried out for the discovery of the anatomical pieces of pig carcasses, in the 24th hour of group number 1, the 72nd hour of group 2, the 336th hour of group 3 and the 662nd hour of group 4 (figure 13), using the same protocol in places where the corpse was removed. The previous results indicate that the findings' sensitivity and specificity at different times increase and the canines' behavioral changes, probably due to the stronger odor cone from the body still present. Likewise, it indicates that in a possible real scenario, the search for places without bodies is more complicated, proving the importance of the realizing the search in the shortest time frame from when the murder or disappearance took place; therefore, there must be an adequate level of sensitivity and specificity by the part of the handler, the first evaluator in the practical field and the third evaluator in the observed video (figure 22).

Sensitivity and specificity of the response of the canine team with the anatomical parts of pig carcasses-double-blind cadaver test, using operative reception curves. A reliability of 92 % is observed, with an almost perfect Kohen kappa among the three evaluators: 1) first evaluator (guide): identifies the dog's alert signal in the place where the corpse is located. (Area under the 0.921 curve), 2) second evaluator: validates what is observed in the real practical field, identifying the alert signal of the dog in the place where the body is present (Cohen's Kappa of 0.913) and 3) third evaluator (video): identifies the dog's alert signal at the place where the corpse is present, through subsequent video observation. (Cohen's Kappa of 0.932).

The results indicate that canines can locate a wide spectrum of scenarios using human decomposition as the target odor when trained with parts of human tissue (bone remains and soft tissue), the liquid product of decomposition (adipocere), blood and even teeth (Nizio, 2017). Currently, Colombian police dogs are trained using a combination of human remains, individual tissues and training with human analogues (Sus scrofa) During the six months of searches, the environmental humidity was between 54 and 66% (average of 60%), which affected the residual smell capable of being detected by the dog, possibly due to rain. This was true in the cases of 48 and 72 hours post removal of the remains. In the places where the anatomical pieces of pig carcasses and human bones were still found, the response is faster, with an average of 5.38 minutes, obtaining alerts such as sitting, lying down, standing, urinating, rolling over or surrounding the body or the area attached to it and in some searches the canine arrived at the site, but did not show any signs.

The results indicate that the time in which the offense takes place and the type of surface where the sample is located can affect the canine's team response, as well as temperature, humidity and air currents. The more time elapses between removing bodies and the detection by dogs, the more difficult it is to locate residual odor, with canines. The aforementioned has direct discrepancies in complicated scenarios such as the Colombian one, where residual organized armed groups (GAOr) continue to profit from criminal economies, "erasing" the material evidence associated with their victims, employing strategies of concealment and elimination of remains, which are buried, cremated or dismembered. Results are better obtained by the canine search group the longer the body has been in contact with the earth or when or when the search's initiation is prompt.

There are advantages and disadvantages to the use of pig and human carcasses for forensic investigation; experiments with human corpse analogs (i.e., pig carcasses) have been easier to replicate and more appropriate to control factors in these types of criminal investigations (Matuszewski, Hall, Moreau, Schoenly, Tarone & Villet, 2020). Even though the corpses of decomposing human analogues (Sus scrofa) are a widely studied source, the responses and validation of dogs still need long-lasting studies, especially when comparing human corpses in different stages of decomposition. A study carried out by Deruyter, Nettles, Ochoa-Torres, Cristancho, Rojas-Guevara, Bohórquez & Prada-Tiedemann (2020), verified that the residual odor remains on the ground after the pig carcasses are removed at different intervals, proving that dogs can detect this aroma over time. Other studies developed experimental designs on human decomposition in the open air (Forbes, 2017; Wallman, 2017), which opened the debate on the relevance of using pigs or humans for taphonomy studies in the forensic analysis (Black, 2017), which empirically corroborated the performance of the binomials, comparing it with other related studies in the field of forensic investigation in other latitudes, under other environmental conditions, humidity, temperature and soil such as the one proposed.

The binomial training protocol has four fundamental stages that guarantee technical reliability within the objective of achieving effective canines and competitive guides. Therefore, no step can be omitted. Furthermore, by omitting any action, there is no guarantee that the canine team will contribute to a criminal scene. The training stages are: 1) selection of ECDRH; 2) technical system for ECDRH training; 3) initial certification of ECDRH and 4) evaluation and permanent certification of the quality of ECDRH. It is essential to obtain the target odor source for the training of corpse detector canines, which has two origins: the first, corresponds to synthetic products made in laboratories, which mimics the original odor of a human corpse as analogs and the second source, are human remains themselves, which is indispensable for canine training.

There are synthetic substances on the market that resemble human odor, which are used for corpse-detecting canine training, as well as substances such as pseudos or analogues (Sus scrofa) where studies have recommend not using them for human decomposition studies (Connor, Baigent & Hansen, 2018) or to investigate postmortem intervals (Fancher et al, 2017). Research has made significant contributions to forensic science, but has not validated the dog's responses in uncontrolled environments such as the one proposed and even less so under uncontrolled environmental conditions in cold climates, which is extensively validated in this book. Therefore, it is necessary to continue with work that impacts criminal investigations, acknowledging a certain level of uncertainty in studies in which environmental factors are not controlled, which are the variables that affect the findings of bodies or their parts. Even in studies faithfully designed for human decomposition, it is inevitable to make adjustments for future studies. Furthermore, this type of research does not have bias to make decisions and validate estimates based on the decomposition of human bodies, analogues or other fields of science.

In this chapter, the results show that the conservation of the bodies lasts longer in cold climates at a height of 2,702 meters above sea level and that an operational synergy is necessary as a canine team to understand the ethological signals of the dog by its handler. Likewise, although the temperature remained between 3 and 23 degrees Celsius when removing the pig carcasses, there were variations in rainfall and humidity that affected the finding of cadaveric pieces, especially 48 hours after the pigs were removed, possibly due to rain. Subsequently, the ECDRHs reached the site where the residual odor existed and reinforced the hypothesis that the amount of time that a decomposing tissue is allowed to come into contact with the soil directly affects the response speed of the canine team.

The manner in which canines select and locate human remains or their analogues in a given area is not fully understood (Vass 2004), therefore; the ethological responses of the dogs with the residual smell of pigs and bone remains were verified taking into account their effect on the search. In addition, it was determined how the variables of time, temperature, humidity, type of soil and air currents affected or did not affect the canine's detection, while checking if the handler identified the alerts. Furthermore, it was shown that that the residual odor that was detected by the canine teams was affected by differences found week to week, while noting that the "moods of the dogs" were at times imperceptible at a behavioral level by their guide. In addition, it is vital to use real corpses as training aids under the standards and validation of the protocols used.

The criminal approach must be reevaluated according to each context, not only when using canines in the field of forensic human sciences, but to collect a variety of evidence and establish the correlation between the suspects and the crime (Filetti et al, 2019), in order to make fundamental contributions when using canine corpse detectors, which is important for criminal investigations, since it can indicate the presence of new forms of evidence that can be accepted in the courts of justice (Furton, Caraballo, Cerreta & Holness, 2015). In Colombia, they must be adjusted according to existing laws with the recommended use of "human forensic farms" to determine the advantages, ethical and legal aspects (Varlet, Joye, Forbes & Grabherr, 2020) for future studies. At the NPC , we are currently working under international standards in order to certify the binomials by using various academic programs to measure the behaviors associated with pedagogical competences, performance indicators and the value as instruments of evaluation of humans (Hernández-Maldonado, Rojas-Guevara & Gallo-Vargas, 2019) and binomials (dog and guide).

1.13 Conclusions

In the case of the police dog, which is considered a working animal at the service of the community and with tangible results, it is necessary to continue studies that generate new knowledge to develop strategies that decrease the figures or adjust protocols, such as when there is a missing person report, the search would begin with human remains canine detectors finding the trace in the shortest time possible providing material elements as evidence for the investigation and culminating in finding the human odor and missing person.

The costs incurred by the public force, logistical, operational and human reinforcement are very high when there is a homicide or missing person's case and involves strategic planning to develop the police service. In problematic areas, such as where crops are harvested, human and animal resources are affected by the environmental conditions of humidity and temperature, which implies an exhaustive selection and training process weighing the values and results of such operations, including estimating the economic value of educating, training and executing a working dog (Arnott, Early, Wade & McGreevy, 2014a). Another human rights issue, related to the problems of armed conflict and poverty, is access to education in the affected territories, with a decrease in formal education, which has generated low social and human development, increasing inequality and employment with "cheap" labor (Castiblanco-Castro, 2020).

Finally, the general evaluation protocol for the certification of canine teams in the NPC is presented. This protocol is designed to evaluate any modality of currently trained canines. Finally, the general evaluation protocol for the certification of canine teams in the National Police is presented. This protocol is designed to evaluate any modality of currently trained canines. The evaluation is applied in two moments: the first is when the canine will be certified for the first time and the second, when applied to already certified canine pairs in order to guarantee their effectiveness. It is made up of the data of the place and date where the evaluation is performed, the basic data of the canine, the verification of minimum quality requirements, where a condition question to be evaluated will be presented a parameterized rubric on a scale from 0 to 100 and the observations generated in the evaluation for each condition verified. Likewise, the provenance, training and health documents are verified; in addition, it contains a basic training guide, which contains the logical sequence to evaluate the rate at which the canine inspects the scene, response, ability to discriminate, autonomy and adaptation of the canine; capacity assessment to detect odor producing materials according to modality. It is also noted if the basic components are detected in each modality by the canine, as in the case of the evaluation for canine detectors of human remains. Finally, the rudimentary test for the guides evaluates the official's competence to handle canines, combined with the data of the evaluating personnel and of the proposed protocol (Annex 1).

1.14 Recommendations

ECDRH performance quantification under uncontrolled environmental conditions and in a real-experimental field as in the case of this study, is a limitation from a logistical point of view in the corpses detect operations. In addition, the effectiveness of these binomials presents restrictions related to environmental factors, type of terrain, having a high control of the canine team, but not of the situation during the binomial registration. Information above represents contingent situations related to operations on the field and in some occasions, it cannot be controlled due to the way executed and not presenting an experimental laboratory design. The results show a starting mark to update protocols and improve standards in complex countries such as Colombia, with multifaceted criminal dynamics. It is necessary to continue studying different strategies to face the criminal dynamics at a national and international level. ECDRH, is proposed as one of the strategies for addressing the cases of deaths and disappearances (Breed & Moore, 2015). In addition, it is recommended as part of the protocol of the inter and multidisciplinary teams that address the criminal investigation in the operational response to face this scourge. Likewise, as a contribution to the discovery of the material probative elements in homicide cases (Filetti et al, 2019); together with the other actors (judicial police, judges, prosecution, attorney, ombudsman, among others), in order to obtain faster results and try to resolve the cases presented.

According to the results, it is necessary to adjust the protocols, trying to address cases sooner ad faster. In addition, a protocol must be set for the use of human remains in different stages of decomposition. Likewise, the approach to real cases must be as quick as possible in a very short time after the offense has been committed, at the time the case is reported and while the family members make the complaint, in order to improve the searching and finding of missing persons, by using canine teams to detect human corpses or their parts, adjusting the operational protocols and the synergy of the two specialties of human odor detecting dogs and also impacting educational programs related to forensic sciences (Williams, Cassella & Maskell, 2017). Operations to detect corpses in the practical operational field, it is complex to quantify the performance of the ECDRH; therefore, this research is a starting mark under uncontrolled environmental conditions, which seeks from an empirical research to understand the behavior of the binomials (guide-dog). In addition, the effectiveness of those teams has restrictions related to environmental factors, the type of terrain, where there is a high percentage of control of the canine team itself, but not of the situation during the registration.

The foregoing represents contingent situations of field operations and in some occasions, it cannot be controlled because it does not present an experimental laboratory design. The results set a starting mark to update and improve protocols standards in such complex countries like Colombia. Dogs have “bad days” or may miss a goal for an unknown reason, making it necessary to choose adapted and tested breeds, including tight genetic profiles. Environmental factors have a greater impact when conducting odor detection investigations, especially when not all variables (wind speed, humidity or temperature) can be fully controlled, which can affect the mechanism of movement of odor through the air, which means that any failure may be attributable to a lack of consistent odor rather than an error on detection by the dog.

2. Analyzing the Effects of Body Wrapping on Rate of Decomposition

Figure 22
National Police of Colombia, canine team.

Note. Patrullero Raquel Parra Duran. Comprehensive Canine Professional Technician Program Student Cohort 13, Belonging to the ESGAC research nursery.

Abstract

When a deceased individual is discovered at a crime scene, it is a crucial piece of information for forensic investigators to determine the preliminary postmortem interval (PMI). Understanding the distinct stages of decay in the decomposition process and how these stages can be affected by various factors is important in determining an accurate PMI. In many homicide cases, bodies are commonly found wrapped in multiple

materials such as bedding and trash bags. Despite existing research on how a body being wrapped affects the decomposition process, there is a lack of this type of research in a climate like that found in West Texas. The purpose of this study is to mimic homicide cases in which victims are found wrapped in bedding or trash bags, to understand how this would affect the rate of decomposition in a dry West Texas climate. This study was conducted using a human analogue model, pig carcasses, (Sus scrofa), because of its similarity to human tissue. This pilot study used six deceased pigs, two as a controlled study, two wrapped in a cotton bed sheet and two wrapped in a black garbage bag. To monitor the timeline at which each stage of decay was observed in the six samples, photographs and detailed visual observations were recorded daily until all decomposition stages were observed. Additionally, daily temperature and weather conditions, as well as soil pH and moisture were included in the data collection. It was hypothesized that the coverings would decrease the rate of decomposition. The purpose of this study is to develop a better understanding of how wrappings affect decomposition by providing research that could advance better estimations of the Preliminary Post Mortem Interval.

Introduction

When a body is discovered at a crime scene, a crucial piece of information for criminal investigators to establish is the Post Mortem Interval (PMI). Postmortem Interval is the time elapsed between the time of death and the moment in which a body is discovered. Determining an accurate P.M.I. is a challenging process because the human decomposition process is highly susceptible to influence by a great variety of factors. Factors that can affect human body decomposition include cause of death, geographical location and subsequent season and climate, exposure to elements, insect activity, burial, and wrapping and concealment. When analyzing homicide trends, patterns exist in which bodies are discovered. Victims of homicide are often disposed of either nude, clothed, or superficially wrapped in easily accessible materials. Common materials utilized in superficial body wrapping include bedding, garbage bags, carpets, and plastic tarps. All instances in which a wrapped body is discovered, and the material used to wrap the body have a potential accelerative or decelerated effect on the decomposition timeline. Therefore, an extensive understanding of real-life applications of how body wrapping affects decomposition will shed light on the forensic field in determining an accurate Postmortem Interval.

2.1 Analyzing the effects of body wrapping on rate of decomposition

2.1.1 Research impact

A limited amount of research has been conducted on how wrappings affect the decomposition timeline. However, because the climate is such an influential factor in the process of decay, conducting decomposition research in various climates is arguably the only way to accurately account for this variable. The purpose of this study was to analyze how a body would decompose wrapped in either a 100% cotton bed sheet or a black plastic trash bag in a dry West Texas climate. The null hypothesis of this study is that both types of wrapping will decelerate the decomposition timeline. It was also hypothesized that the specimens wrapped in the black trash bag would decompose faster than those wrapped in the cotton bed sheet.

2.1.2 Decomposition timeline

Existing research on the decomposition timeline outlines the stages of decay in various ways. The vast majority of prior research divides decomposition stages in a longitudinal phase arrangement categorized as fresh, bloat, active decay, advanced decay, and dry or remains. Differences are found in literature in the way stages are outlined because researchers often couple stages together or use a slightly different term based on individual preference. For instance, in Cahoon (1992), the active decay and advanced decay stages are referred to as decay, as well as Dautartas (2009), where similarly, these two stages are referred to as decomposed. Similarly, in Voss et al. (2011), dry / remains is referred to as skeletonization and advanced decay is referred to as wet. Overall, the way the researcher decides to differentiate stages is largely unimportant because the physical and chemical processes are crucial to understanding the process of decomposition. Subsequently, for this reason some literature does not designate stages and describes the decomposition process by simply providing explanations of the key processes that take place (Miller, 2002; McDaneld, 2016). However, for this study, both will be provided. The decomposition timeline stages will be outlined as fresh, bloat, active decay, advanced decay, and dry or remains and will include the correlating chemical and physical processes that occur.

2.1.3 Fresh stage

Almost immediately after death, oxygen ceases to circulate throughout the body, causing the cells to die. They succumb to enzymes that begin to consume these cells in the process of self-digestion called autolysis (Vass, 2001). During autolysis, blisters are formed internally, and externally and skin cells are shed from the epidermis, which together, often leads to skin slippage. In addition to autolysis, during the first couple of hours after death, blood begins to settle inside the body in a process called livor mortis. Livor mortis can be observed by the presence of red and purple patches in color. Their location on the deceased is entirely dependent on the body's positioning and how gravity causes the blood to pool. Once this occurs, it is said to become fixed within 12 hours (Goff et al. 2010).

During the first 24 hours after death, the body additionally undergoes rigor mortis, a stiffening of the muscles. This process occurs due to cells not functioning properly from the cessation of oxygen circulation within the body (Vass, 2010). It can be first observed in the first 2 to 6 hours following death, beginning in the head and neck regions and eventually affecting all the muscles within 4 to 6 hours after death. After 24 hours or even up to 84 hours post mortem, the muscles relax in a pattern mimicking the onset of rigor, starting with the head and moving toward the lower body, eventually disappearing altogether (Goff et al. 2010).

As a result of the body no longer being able to self-sufficiently regulate the internal temperature, it undergoes algor mortis, the cooling of the tissues to match its surroundings' temperature. It was reported in the literature that internal temperature would decrease by 0.8 degrees Celsius every hour after death (Vass, 2010). However, a closer look at the literature on algor mortis reveals several possible shortcomings to this seemingly simple equation. A more comprehensive understanding can be found in (Goff et al. 2010), where it is emphasized that the rate at which algor mortis occurs can be affected by factors such as external heat sources and body mass.

2.1.4 Bloat stage

By the bloat stage of decomposition, the amount of bacteria and microbes has greatly increased. A process called putrefaction occurs where microorganisms including bacteria, fungi, and protozoa, begin to break down tissues (Swann et al. 2010). The activity of these microorganisms produces gases and liquids inside the cavities of the body that causes the tissues to bloat (Vass, 2001). The body begins to display an appearance that can be characterized as swollen and puffy. The most commonly observed portion of the body to appear the most distended is the abdominal region due to the large natural presence of bacteria found within the organs located in the abdominal cavity (Vass, 2010). It is also common to observe green discoloration of the tissues during this stage. Eventually, the accumulation of pressure causes the expulsion of these gases and fluids through the orifices of the body and even sometimes the rupturing of the abdominal cavity.

2.1.5 Active decay stage

Once fluids and gases are purged from the body, the next decomposition stage begins, active decay. It is often observed that the carcass's thorax and abdomenhave collapsed (Miller, 2002). As a result of the ruptures, oxygen is allowed back into the issues, increasing maggots' activity and anaerobic microorganisms (Carter et al. 2007). Further breaking down of tissues results in the production of a greasy wax-like decomposition fluid, often referred to as either Saponification or adipocecre formation (Vass, 2001). During the active decay stage, the body's discoloration is also observed to be visibly more extensive, often presenting extreme discoloration (Miller, 2002). This is typically seen through a dark green or even a black coloration of the epidermis.

2.1.6 Dry / Remains stage

The dry remains stage can be characterized by the absence of tissues or decomposition fluids. The only matter that can still be observed is bones. Bones have their own decomposition process called digenesis, a process that takes a considerably longer amount of time than any of the aforementioned stages (Swann et al. 2010). Digenesis begins by first the proteins in bones being broken down. The absence of proteins leaves minerals solely behind, making the bones very fragile. Breakage by environmental factors and scavengers will eventually erode the bones down into dust (Vass, 2010).

2.2 Factors affecting decomposition

Many factors can influence the duration of the aforementioned five stages of human decomposition. As mentioned, disparities in research regarding how long these stages last are attributed to variance in influential factors and even the natural bias that comes with research observation (Srnka, 2003). The decomposition timeline's most influential factors include temperature, moisture, insect activity, sunshade, or exposure.

2.2.1 Temperature

Temperature is arguably the most influential factor that plays a role in the human desiccation process. Higher temperatures will accelerate the velocity at which the decomposition process occurs at a faster compared to lower temperatures (Payne-James et al. 2011). This is mainly due largely to the effect temperature has on the rate at which chemical reactions occur. Each 10 degrees Celsius increase in ambient temperature accelerates the decomposition timeline at a rate that is two or more times faster than before (Swann et al. 2010). Additionally, high temperatures generally permit more favorable conditions that allow for a greater abundance of insects and microorganisms present in both the soil and environment (Ioan et al. 2017). However, oftentimes scavenger activity is more present in low temperatures, as winter months make it harder for animals to acquire food sources. This can be seen in Miller (2002), a study conducted using human cadavers to assess the effect of clothing on the human decomposition timeline during winter and comparatively summer seasons. It was concluded that scavenger activity was higher during the winter trial, likely because of food sources' competition occurring among the local animal populations (Miller, 2002).

2.2.2 Insect activity

Arthropod succession during the decomposition process is predictable and therefore studied by entomologists and criminal investigators when determining what stage of decomposition tissues are. In as little as 10 minutes after death (Vass, 2010) flies are drawn to the body's moist areas including orifices or any wounds present on the carcass. Oviposition by adult female flies typically hatch into maggots in around 8 to 14 hours (Miller, 2002). Maggot activity is a major driving force in the decomposition timeline because they are largely responsible for consuming the body's soft tissues (Carter et al. 2007). Varying environmental conditions as well as the state of the carcass i.e., whether it's submerged, buried, or wrapped, can also increase or decrease the amount of insect activity present (Nizio et al. 2017).

2.2.3 Sunshade and exposure

A majority of prior research suggests that temperature increases the rate at which decomposition occurs therefore, it is logical to assume that carcasses exposed to direct sunlight will decompose at a faster rate than those in the shade. However, this is not always the case. Sunlight has a direct effect on insect activity, and it can either accelerate it in some cases by stimulating maggot activity or, in other cases, discourage oviposition by female flies altogether in the presence of direct sunlight (Srnka, 2003).

2.3 Previous studies involving wrapping

2.3.1 Clothing

The most substantial amount of research on how wrapping effects the decomposition timeline has been conducted regarding the effect of clothing. As aforementioned, insects are one of the major driving forces in the decomposition process. As a result, multiple researchers have placed an importance on developing a further understanding of how wrappings affect arthropod succession (Kelly et al. 2009; Voss et al., 2011). To make these types of experiments as realistic as possible, researchers often dress research subjects in clothing that would most likely be worn by humans in daily life.

Miller (2002) conducted an experiment over the duration of a year regarding clothing on the decomposition timeline of human cadavers in Knoxville, Tennessee. During the warmer months, the cadavers were dressed in a t-shirt and sweatpants, and during the cooler months in a t-shirt, sweatpants, and a sweatshirt. The experiment revealed a negligible correlation between clothing and decomposition during the winter months. However, in the spring and summer months, it was seen that the clothing decelerated decomposition. Miller (2002) proposed it takes a clothed cadaver around 1.7 times the additional time in the spring to decompose and 2.0 times the additional time in the summer to decompose to the same extent as an unclothed cadaver. These findings were attributed to clothing acting as a factor that retards the epidermis decomposition, in turn, accelerating mummification.

Voss and associates (2011) conducted an experiment in Perth, Western Australia, to analyze how cotton T-shirts, coupled with shorts with an elastic waistband would affect carcass decomposition and insect succession. Utilizing 10 pigs, Sus scrofa, it was observed that both clothed and unclothed specimens progressed through the fresh and bloat stage simultaneously. The only difference found in these two preliminary stages was that in the bloat stage, the pants' waistband constricted the distention of the abdomen, causing ruptures in this area. Additionally, clothed specimens remained in the active decay stage longer, as well as took a substantive amount of additional time to achieve skeletonization than the unclothed remains. By the end of the experiment, all that remained of the control carcasses were skeletal remains while the clothed carcasses only partially exhibited skeletonization. In regards to insect succession, it was observed that there was more insect activity occurring underneath the clothing of clothed carcasses versus unclothed carcasses where insect activity was focused inside and underneath the carcass. Interestingly, prior research approximates a 2.5-day delay of initial female fly oviposition on wrapped carcasses (Goff, 1992), yet Voss et al. (2011) recorded that oviposition occurred simultaneously regardless of the presence of wrappings or not.

Phalen (2013) experimented during May and June using three human corpses at the Forensic Anthropology Research Facility in San Marcos, Texas. The clothing used in this experiment included sweatpants of a blend of 55% cotton and 45% polyester and well as sweatshirts made of 60% cotton and 40% polyester. The most evident conclusion was made regarding skeletonization which was observed in a greater degree in clothed individuals versus unclothed individuals. This was attributed to the clothing providing shelter for insects from intense UV rays, which can result in maggot mortality and the retention of moisture, ideal for the life cycle of fly larvae. Additionally, it was found that clothing affected the discoloration of the epidermis. As a result of bloating, the stomach of clothed cadavers were exposed to ultraviolet (UV) rays, causing them to appear lighter in color in comparison to covered portions of the epidermis. Phalen suggested that forensic investigators should take this into account when observing a clothed discovered body. If the discoloration pattern does not match the location of the clothing, there is a likelihood that taphonomic events moved the placement of clothing post-death.

Matuszewski et al. (2014) conducted an experiment intending to understand the effect of the presence of trousers and a t-shirt or blouse as well as a varying body mass size on the decomposition timeline. This study utilized 24 pig carcasses, Sus scrofa, as research specimens, the demographics of these subjects fit into four different levels of carcass mass size. In regard to clothing, a negligible effect on the decomposition timeline was observed. Matuszewski attributed this to the clothing being "moderate", and that heavier clothing would likely have a more profound effect. This is contradictory to Voss et al. (2011), where similar clothing prolonged the latter stages of decomposition. It was revealed that the larger carcasses began and remained in the bloat stage for longer than the smaller carcasses. All mass sizes entered the active decay stage simultaneously however, larger carcasses remained in this stage for a longer duration than smaller carcasses.

Limited research exists involving two materials being tested simultaneously. This is interesting because the likelihood of a body being discovered in clothing as well as superficially wrapped in some material is logistically just as high. An experiment conducted in Bloemfontein, South Africa by Kelly et al. (2009) bridges this research gap by using 8 pigs, Sus Scrofa, to see how clothing, wrapping, and a combination of clothing and wrapping affects the decomposition timeline as well as the succession of insects. The research materials included T-shirts, shorts and male brief underwear as well as medium weight cotton sheeting. Similar to Voss et al. (2011), the rate at which decomposition progressed was simultaneous until the latter stages of decomposition. The unclothed unwrapped specimens reached skeletonization while the clothed wrapped specimens were still in the advanced decay stage. Again, the insect's initial activity was not prolonged by the presence of wrappings and maggot distribution was highest underneath clothing, specifically observed to be most focused in the shorts and waistband area.

2.3.2 Cotton bed sheet

Cotton is of the most common materials used in the manufacture of bedding, and, for that reason, is an important research material in decomposition studies. Bell (2013) conducted a study in San Marcos, Texas, utilizing 3 pigs, Sus Scrofa as research subjects. Of these 3 subjects, one was wrapped inside a cotton bed sheet. The specimen subjected to this wrapping showed signs of accelerated decomposition in comparison to the unwrapped control. This was attributed to insect activity and that cotton is a naturally absorbent material. The sheet was observed to have created a sheltered environment that allowed insect activity to flourish. Additionally, it was noted that the specimen wrapped in the cotton bed sheet underwent less skeletonization, likely because the sheet retained both moisture and precipitation, keeping the tissues from drying out.

Dautartas (2009) conducted a study done in two repetitions to analyze a cotton blanket's effect on the decomposition timeline of human cadavers. In each repetition, 3 cadavers were utilized; one wrapped in a cotton blanket, another wrapped in a plastic tarp, which will be discussed in section 1.4.4, and the other left unwrapped as a control. It was concluded that the extent of mummification was much more prevalent in individuals wrapped in the cotton blanket versus the unwrapped cadavers.

2.3.3 Black trash bags

In the aforementioned study done by Bell (2013), the other research material that was utilized in the study was a black plastic garbage bag. It was concluded that the specimen wrapped in the garbage bag decomposed at a faster rate than the unwrapped specimen. This was attributed to the material facilitating a heightened presence of insect activity as well as an increased internal temperature. In the aforementioned study done by Bell (2013), the other research material that was utilized in the study was a black plastic garbage bag. It was concluded that the specimen wrapped in the garbage bag decomposed at a faster rate than the unwrapped specimen, this was attributed to the material facilitating a heightened presence of insect activity as well as an increased internal temperature. The black trash bag provided a sheltered environment from various climate factors which in turn allowed insect activity to occur undisturbed and uninterrupted. Additionally, the materials dark color attracted the sun's rays causing the internal temperature of the bag to rise and the creation of an insulated environment.

2.3.4 Plastic tarps

McDaneld (2016) conducted an experiment to test how a plastic tarp with dimensions 10 x 12 ft. would affect the decomposition timeline of human cadavers wrapped in this material. The sample size of this study consisted of 10 cadavers wrapped in the plastic tarps and 6 unwrapped cadavers to serve as controls. The experiment revealed that the cadavers wrapped in tarps decomposed at a notably faster rate than the cadavers left uncovered. This was attributed by the researcher to be a result of the tarp likely retaining moisture and giving maggots a sheltered environment from climate factors. This conclusion is similar to other studies that suggest wrappings create an ideal environment for insect activity to take place (Kelly et al. 2009; Voss et al. 2011; Bell, 2013).

In the study mentioned earlier conducted by Dautartas (2009) the other material that was utilized in the experiment to assess its effect on the decomposition of human cadavers was plastic tarps. It was concluded that in comparison to the cadavers wrapped in the cotton blanket and unwrapped cadavers that the most profound effect on decomposition was seen in those individuals wrapped in the plastic tarp. By the end of experiment on day 31, all other specimens in the sample exhibited some extent of mummification while the individuals in the plastic tarp displayed no mummification. Instead there was a profound amount of moist decomposition, remaining tissue and an ample presence of adipocere. Despite continuing and existing research on how a body being wrapped affects the decomposition process, of crucial importance for enhanced postmortem interval estimation methods is the need for a robust data set constructed across various longitudinal timelines and geographic locations. Thus, the aim of this study is to assess the effect of two distinctive wrapping materials with a human-analogue model in a West Texas environment. Results obtained would add knowledge to environmental impact on this forensic taphonomy variable and provide practitioners key information in forensic contexts.

2.4 Experimental schematics

2.4.1 Study location

This experiment was conducted at the Institute for Forensic Science at Texas Tech University, located in Lubbock, Texas. The Institute has a designated and secluded field space for the use of conducting decomposition research. According to the Koppen climate classification, the climate of Lubbock, Texas, is classified as Tropical and Subtropical Steppe Climate. This region has low humidity, with a yearly average of 44.5%, as well as low precipitation averaging at 18.9 inches. It is one of the windiest cities in America, with wind speeds averaging at 12.4 mph. Lubbock is also home to reasonably distinct seasons. Winter months are typically cold and cloudy, with temperatures averaging 4.4°C (40.0°F) in its coldest month January. Comparatively; the summer months are hot with clear skies, the warmest month is July, with an average temperature of 26.2°C (79.2°F).

The climate of Lubbock is very similar to that of a desert, it is home to fine and mixed soils, as well as short to mid-level grasses.

2.4.2 Research subjects

As a result of human cadavers not being available for utilization as experimental specimens, six pig carcasses Sus scrofa were utilized as research subjects. Sus scrofa is the most frequently used analogues for humans in decomposition research (Matuszewski et al. 2020) because of their similarity to human tissue. All six pigs were of similar weight, all weighing less than 3 pounds. The pigs were acquired through donations from Animal Care Services at Texas Tech University's Animal and Food Sciences Department and Wintex Farms. Due to logistical reasons, the piglet carcasses were stored in a laboratory freezer at -80°C before field use due to carcass donations before experimental set up. Before laying out the pigs on the field test site, they were completely defrosted. Although it was acknowledged that this procedure can cause an alteration to the animal model (Micozzi, 1986), literature has highlighted that reduced bacterial activity at lower temperatures simulates limited bacterial activity of neonatal remains (Archer, 2004). On February 25, 2019, the pigs were removed from the freezer at 8:55 A.M. and left to thaw until 3:00 P.M. that afternoon.

2.4.3 Research materials

Materials required conduction of this experiment included Hefty Strong Multipurpose 30 Gallon Large Trash Drawstring Bags (Reynolds Consumer Products Inc, Lake Forest, Illinois) and a Queen 300 thread count 100% cotton bed sheet, color white (Better Home and Gardens, Walmart Incorporated; Bentonville, Arkansas). According to data compiled by Statista, originally from the U.S. Census and the Simmons National Consumer Survey (NHCS), Hefty is the most popularly used trash bag in the United States. This particular survey consisting of approximately 330.27 million American respondents, 117.05 million preferred Hefty trash bags and liners. Therefore, this specific type of garbage bag was chosen as a research material because of its likelihood to be a common household item, along with its large size and the dark color being a likely choice to conceal a human body. The bedsheet selection was made due to its common use as a frequent type of bedding found in households. Given the small size of the research subjects, the cotton bed sheet was cut into smaller, more easily manageable sections. Two segments were cut from the bed sheet, measuring 50 inches in length and 25.5 inches in width each.

2.4.4 Study setup

On February 25, 2019, at 4:30 P.M., six metal cages were placed in an unshaded area of the designated field space, cages were utilized to deter scavengers. The cages all contained trays. These trays were removed to allow contact between the soil and the research specimens inside each cage. The cages were labeled with painter's tape and were referred to as "Control Cage", "Cage 1", "Cage 2", "Cage 3" and "Cage 4" for the duration of the experiment Orange construction flags were placed in front of each cage to mark where the soil's pH and temperature would be recorded daily. The field was home to various short grasses and weeds, none of which were removed to keep the experiment as natural and realistic as possible. A photograph showing the experimental set up can be seen below in (Figure 20)

Figure 23.

Set up of experimental site on Day 0.

At 4:34 P.M., two pigs were removed from the bags in which they were held in the freezer and placed inside the "Control Cage". The pigs were left unwrapped, to allow for daily observation, photographic evidence and to act as a comparison model to the wrapped subjects. Two control subjects were used as a proactive measure to prepare for the possibility of any problems to arise with one of the control specimens.

2.5 Wrapping processes

The research subjects' wrapping process was done in a similar manner, depending on the material being utilized to make the experiment as uniform throughout as possible. The wrapping process for the cotton bed sheet was done by placing a pig at one end of the sheet, rolling the carcass inside the sheet until all the material was wrapped fully around the subject, and taking the excess material on either side and tucking it underneath. The two research subjects that were wrapped in the cotton bed sheet were placed inside cages 1 and 3 by 4:44 P.M. The wrapping method for specimens wrapped in the black garbage bag was done by first opening the garbage bag, placing the subject at the very bottom and was followed by tightening, and lastly tying off the drawstring. Starting with the top of the bag, the material was rolled end over end until the specimen was reached. Lastly the excess material on either side was tucked underneath. The two specimens that were wrapped in the black garbage were placed inside cages 2 and 4 by 4:53 P.M. A more illustrative demonstration of the wrapping processes for this study can be seen in figures 2 and 3 below.

2.6 Data collection

Data collection took place daily at 3:40 P.M., with day 13 and day 20 were the days where experimental carcasses were removed from their wrappings to observe decomposition status. Daily observations included detailed visual observations and extensive photographic evidence of control subjects as well as any observations of cages 1, 2, 3 and 4 if available. A table was created o score decomposition based on a loose interpretation of similar decomposition scoring tables found in prior research (Megyesi et al. 2005). The table 6, was used to score research subjects, serve the purpose of quantitatively describing the apparent stage of decomposition based on the observation of a series of characteristics. For this study, a scoring table was created to measure daily decomposition development. Scores were calculated by allotting points based on the characteristics observed in the table. Each day a new characteristic was observed it was added to the score of the previous day. For wrapped specimens since they had logically progressed through the fresh stage on the days they were examined, this point was allotted to the score regardless of the researcher observing it. This data collection method allowed for a quantitative comparison of how the decomposition of each subject progressed from day 0 to the cessation of the experiment on day 20 (table 6).

Table 6.
Decomposition Scoring

Stage	Characteristics	Scoring
Fresh 1 pt.	Still retaining natural pink color with no discoloration	1 pt.
Bloat 2 -28 pts.	Purging or presence of fluids	2 pts
	Slight discoloration around abdominal, head and neck regions	3 pts
	Swollen appearance	4 pts
	Prominent dark green discoloration of AB, HN regions	5 pts
	Skin slippage or sagging	6 pts
	Carcass discoloration nearing black color	7 pts
Active decay 29-45 pts	Progression of discoloration to a prominent black color	8 pts
	Carcass body cavity sunken, skeletal frame visible beneath skin	9 pts
Advanced decay 29-45 pts.	Limited bone exposure observed	10 pts
	Bones still have decaying flesh and decomposition fluids	11 pts
Remains 67-78 pts.	Bones dry	12 pts

To account for climate and environmental factors, daily data collection also included temperature, wind speeds, humidity, UV index, as well as pH and soil moisture. All weather-related variables were recorded through the local weather station, KCBD. The weather station is located at 5600 Avenue A Lubbock, TX. 79404, approximately 15 miles from the experiment site. Subjects in cages 1, 2, 3, and 4 were left undisturbed in their wrappings until their specified day of opening. This was done to most closely mimic a real-life application.

On day 13, the material wrapped around subjects in cages 1 and 2 was cut open with scissors, carefully to avoid puncturing any tissues. The material was then carefully pulled back to reveal the subjects. The wrapped specimens were then compared to one another to see any differences the decomposition rate that could be attributed to the material of the two different wrappings. Additionally, they were compared to the controls to analyze if the wrapped specimens showed signs of accelerated or decelerated decomposition in comparison to an unwrapped subject. On day 20, the same methodology as day 13 was employed. Both days of opening, detailed visual observations were recorded to score decomposition as well as extensive photographic evidence was taken. Once they were opened and underwent observation subjects were disposed of properly so that they would not interfere with the continuation of the experiment.

2.7 Results

1. Day 13

On day 13 of the experiment, both control specimens appeared to be simultaneously approaching the end of the bloat stage (Figure 21). This was deduced by the observation of several characteristics that are recognized in research to be custom to this particular stage. Both control pig 1 and 2 had a presence of dried fluid around the orifices of the mouth, snout, as well as underneath both carcasses. The tongue of each specimen was visibly dried out, likely from being subjected to direct sun exposure as well as other elements. The two control specimens had prominent green discoloration of the abdominal cavity as well as the head and neck regions. Skin slippage and sagging were observed in the neck area and the crevices where the limbs meet the underbelly of the specimen. On day 13, there was only a light presence of insects on each control carcass, around 1-2 blowflies. While control pig 1 had no apparent oviposition by female adult flies, oviposition was observed on control pig 2 in the same area where the aforementioned skin slippage and sagging were present.

There were limited disparities seen between the rate at which each control specimen progressed from day 0 to day 13. However, control pig 2 was observed to be slightly more discolored as well as still noticeably bloated in comparison to other control. This variance was attributed to control pig 2 being a slightly larger mass size. This is supported by research conducted by Matuszewski and colleagues in (2014) who studied wrappings in addition to the decomposition of varying mass sizes of pigs, Sus scrofa. In this study, it was concluded that the bloat stage of larger carcasses lasted considerably longer in comparison to smaller carcasses. Additionally, the mouth of control pig 2 was slightly more ajar, likely allowing for more insects to enter the carcass through this orifice. An increase of insects and microbial inside the body cavity could have likely increased the amount of fluids and gases produced by these organisms, in turn increasing the appearance of bloat. Besides these minor differences in observation, the two controls exhibited the same characteristics designated in the decomposition scoring table and therefore were both allotted 21 points.

On Day 13, the first set of wrapped specimens in cages 1 (cotton wrapped) and 2 (plastic bag wrapped) were carefully cut open for observation. It was evident at this time that the presence of wrappings had hindered the progression of the decomposition timeline in comparison to the unwrapped controls (Figure 22). The specimen in cage 1, wrapped in the cotton bed sheet, appeared to be only in the onset of bloat. The observed lack of progression of the decomposition of the specimen would have made it difficult for the researcher to determine the stage if not for the presence of a fairly large amount of fluid that had stained the sheet. However, in opposition to the controls, there was no discoloration, swollen appearance, or the presence of insect activity. Based on the characteristics delegated by the decomposition scoring table, the specimen was allotted a score of 3.

The specimen in cage 2, wrapped in the black garbage bag, was similarly behind in its progress in the decomposition timeline by day 13 (Figure 23). However, it was slightly more advanced than its counterpart, as it was observed to be farther along in the bloat stage. The bag's opening revealed an abundant presence of fluids underneath the carcass as well as the presence of bloated tissue. There was slightly more discoloration, but in opposition to the green color observed in the epidermis of the controls the skin of the specimen in cage 2 exhibited a red / pink color. According to the characteristics observed on this day the specimen in the black garbage bag was scored at 10 points.

On day 20, the last day of experimentation, the decomposition of controls had noticeably progressed to a much father extent compared to day 13, as both controls appeared to be well into the active decay stage. The discoloration was observed to be much more severe, covering a larger surface area of the epidermis as well as having advanced to a prominent black color. The body cavities of both control channels appeared sunken. Although no bone was observed, the skeletal framework could be clearly seen under the skin, assigning a score of 45 points in the state of decomposition on the timeline. The only observable inconsistency between the two controls was that the larger control pig appeared to have more mass loss. It was also noted that there was a significant increase in insect activity on this day with 4-5 blowflies present on each carcass.

The pigs in cages 3 (cotton wrapped) and 4 (plastic wrapped) were additionally observed on day 20. There appeared to be only a slight progression of the decomposition of the specimen in cage 3, as it appeared to be farther along in the bloat stage in comparison to only being in the onset of bloat on day 13. The sheet was stained with decomposition fluid, and there appeared to only be a slight discoloration best described as blanched appearance of the epidermis. The discoloration presented itself as a new characteristic and therefore the specimen was allotted 6 points. The progression of decomposition of the specimen in cage 4, wrapped in the black garbage bag was negligible. There was no observation of new characteristics, and therefore it was allotted the same score as day 13, 10 points. Additionally, it was once again observed that both wrappings prevented insects from accessing the carcass. Photographic evidence of the controls, as well as specimens in cages 3 (cotton wrapped) and cages 4 (plastic wrapped) on their day of opening, can be seen in (Figure 24).

Experimental Results for Wrapped Specimens at Day 20 Decomposition Timeline

(Figure 25), is a compilation of all decomposition scores collected for the duration of this experimental study. As can be observed, both controls had a progression of scoring as a function of decomposition stage reaching a maximum of 45 points. Both carcasses wrapped in the cotton sheet had the lowest scores as a function of the decomposition stage, with only 3 points on day 13 and 6 points on day 20. The specimens in the black plastic bags displayed a negligible increase of scoring, with 10 points on day 13 and also 10 points on day 20. Therefore, these results emphasize that body wrappings, both cotton and plastic, delay decomposition stages progression.

Figure 24.
Photographs illustrating the process of wrapping subjects in the cotton bed sheet on day 0.

STEP 1: Place pig in the center of one end of the Cotton Bed Sheet

STEP 2: Roll until the full length of the sheet is wrapped around the pig

STEP 3: Take excess material on sides of pig and tuck underneath

Figure 25.
Photographs illustrating the process of wrapping subjects in the black garbage bag on day 0.

STEP 1: Place pig inside the bottom of a Black Trash Bag

STEP 2: Take top of Black Trash Bag and roll until the pig is reached

STEP 3: Take excess material on sides of pig and fold over on top, flip over so excess lies underneath

Figure 26.
Experimental Results for Wrapped Specimens at Day 13 Decomposition Timeline.

Figure 27.
Compilation of all decomposition scores collected for the duration of this experimental study.

Day 20 Observations

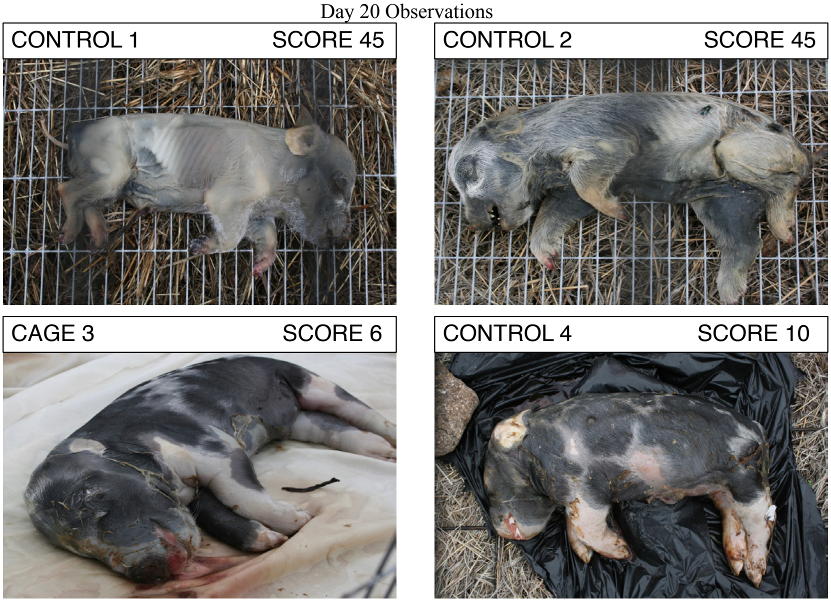
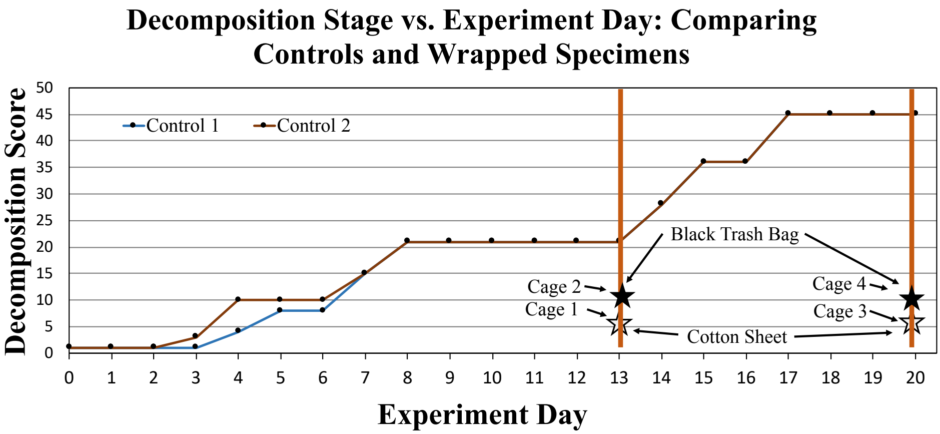


Figure 28.
Russ experiment day: comparing controls and wrapped specimens.



2.8 Discussion

The null hypothesis of this study was supported, both the cotton bed sheet and black trash bag decelerated the decomposition timeline of wrapped specimens in comparison to specimens left unwrapped. This finding was contingent on the vast majority of prior research that concludes wrappings often decelerate the decomposition timeline of wrapped specimens (Miller, 2002; Voss et. al 2011, Kelly et al. 2009). The cotton bedsheet displayed the highest decomposition delay parameter, with the lowest scores during the study timeline. On day 13 of experimentation, the specimen wrapped in the cotton bed sheet was only at the beginning of the bloat stage while both controls were nearing the end of the bloat stage. Similarly, 7 days later on day 20 of experimentation, the specimen wrapped in the cotton bed sheet remained in the bloat stage while the unwrapped controls were well into the active decay stage. These results were somewhat surprising, of the prior body wrapping studies done the experiment that most resembles this study, Bell (2013) conducted in San Marcos, TX, found that the specimen wrapped in the cotton bed sheet decomposed at a faster rate than the unwrapped control. This was attributed to the insect activity that was observed inside the cotton bed sheet and this factor was given a large responsibility to the observed acceleration of the decomposition timeline. However, in this study on the days of opening, no insect activity was observed on any of the carcasses wrapped in the cotton bed sheet. Perhaps the reason as to why the specimens wrapped in the bed sheet showed delayed decomposition was due to the manner the sheet was wrapped around the specimens. It is possible that tighter wrappings permit insect access and therefore protected the carcass from the organisms that are a major catalyst to decomposition for their role of consuming the body's soft tissues. Additionally, the absorbency that is a characteristic of the cotton material likely caused the sheet to retain moisture and precipitation, which subsequently kept the specimens from drying out. Temperature has been known to accelerate the rate at which decomposition occurs. Therefore, the sheet likely acted as a protective layer from direct UV rays, likely resulting in the decomposition's timeline retardation.

The black garbage bag wrapped specimens also decomposed at a significantly slower rate in comparison to the unwrapped controls. Similar to the cotton bed sheet from Day 13 to Day 20, the black trash bag wrapped specimens were in the bloat stage while the unwrapped controls by the end of experimentation were now in the active decay stage. These findings were contrary to what has been seen in prior research, such as in the aforementioned study done by Bell (2013), where the specimen wrapped in the black garbage bag decomposed at a faster rate than the unwrapped control Another prior study by McDaneld (2016) using a comparable material, plastic tarps, found that cadavers wrapped in the plastic tarps decomposed faster than cadavers left unwrapped. Similarly to the bedsheet, this was attributed to the bag acting like a protective layer that prohibited insects from infiltrating the carcass and furthering decomposition. The bag is also made of plastic, which emanated a lack of permeability that otherwise would have allowed liquids to escape. This resulted in a large accumulation of decomposition fluid around the tissues, reasonably keeping them moist. However, carcasses in the black garbage bag decomposed at a notably faster rate than specimens in the cotton bed sheet. This was accredited to the dark color of the trash bag which, as expected, would logically absorb more heat from the sun in comparison to a white-colored bed sheet. This prompted the bag's internal temperature to rise and coupled with the abundance of moisture present, the creation of an insulated environment. From prior research about the factors that affect decomposition, it is plausible to conclude that the grounds as to why specimens decomposed at a slightly faster rate in the black garbage bag is in response to the increased rate of chemical reactions that were provoked by an increase in the internal temperature of the bag.

2.9 Conclusions

This study's aim was to evaluate the effect of two distinctive body wrappings on the progression of decomposition of a human analog model, Sus scrofa. Although body wrappings are an important factor when studying the decomposition timeline, the majority of prior research that has been conducted in the past has utilized clothing as the experimental material (Miller, 2002; Voss et al. 2011; Phalen, 2013; Matuszewski, 2014; Kelly et al. 2009). Therefore, this study has contributed to studying the effect of cotton bed sheeting and black trash bags on the decomposition timeline more in-depth. For this study, six pigs, Sus scrofa, were placed in a designated field space intended for decomposition research by the Texas Tech Institute for Forensic Science located in Lubbock, Texas. The vast majority of prior body wrapping studies have taken place in climates where higher amounts of humidity and precipitation are present in central Texas (Bell, 2013; Phalen, 2013; McDaneld, 2016) and the eastern United States (Miller, 2002; Dautartas, 2009). Therefore, this study has extended the geographical parameter of body wrappings studies to include West, Texas, an environment unique due to its cold and dry climate. The duration of the experiment took place over 20 days, beginning in February and ending in March. Extensive observations were made daily over the two unwrapped controls and the wrapped specimens on their perspective days of opening. Other daily data collection included climatic and environmental variables to account for their possible influence on the research specimens' decomposition timeline. Observations were used to score specimens to quantitatively express each specimen's progression through the decomposition timeline and allow for comparison between unwrapped controls and specimens wrapped in either the black trash bag or cotton bed sheeting.

The wrappings presence resulted in a significant reduction in the rate of decomposition of wrapped specimens versus specimens left unwrapped. By the end of the experiment, both wrapped specimens remained in the bloat stage while the controls were in the active decay stage. The wrapped specimens were likely behind in the decomposition timeline due to a shielding effect wrappings can create from environmental elements, insect access, and scavenger activity. It was also concluded that the cotton bed sheet delayed the decomposition of wrapped specimens more than the black garbage bag. The reason why specimens in the black garbage bag decomposed at a faster rate is likely because of the presence of putrefaction liquids inside the bag. While the fluids could seep out of the cotton material easily, the fluids were unable to escape the black garbage bag, likely enhancing bacterial production and accelerating decomposition.

2.10 Future research

A longer period of data collection would have been ideal for this study because it would have allowed the researcher to observe the specimen's progress through the entirety of the decomposition timeline. In this study, samples were left undisturbed until their designated day of opening to prevent any influence by the researcher and make the experiment as applicable to real-life as possible. A larger sample size would have allowed more days of opening and subsequently, a better understanding of how specimens progress along the decomposition timeline when subjected to wrappings. Human cadaver's utilization is logically the best research subject for decomposition studies if they are available for experimental use. Future studies should continue conducting experiments that test the effect of different types wrapping, multiple layers of wrapping, and a variety of clothing, given that many of the clothing worn by individuals today consists of a variety of material other than solely cotton. Future researchers should conduct experiments in varying climates, terrains, seasons, and states of disposal to bridge the existing research gap of these types of decomposition studies, i.e., buried, submerged, suspended, etc.

An enhanced understanding of the effect of body wrappings on the human decomposition timeline will allow forensic practitioners to estimate the postmortem intervals better.

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Annex 1

Proposed Protocol to certify canine detection equipment.

Entity or unit requesting certification:	
City and date:	

Section 1: Basic canine data:

P To identify the microchip in the canine, all types of collars or harnesses must be removed, in case the canine has more than one microchip, the documentary support of the origin must be presented.

Microchip	Name of the canine	Breed	Sex
Color	Birth date	Affiliation number	Specialty type

Reason for canine evaluation

First time certification		Maintenance of certification		not foreseen siagnosis		Termination of service	

First time: refers to the K-9 team that finishes academy and will go out to fulfill an operational function; maintenance of certification: refers to operational K-9 equipment; unexpected diagnosis: applies when it is required to evaluate a K-9 equipment in an extraordinary way; Loss of service: applies when it is required to evaluate a canine by the end of its useful life.

Section 2: Documentary background of canine acquisition, selection and specialization

When it comes to canines for first time certification, all literals apply; When the object is to maintain certification, the factors of literal c) are evaluated from the (Document of aptitude of the canine signed by canine guide, instructor or canine preparer).

Condition to evaluate	Rubric	Scale	Observations
to). The origin of the canine is donation.	Offer letter	Complies__ Does not comply__Not applicable__	
	Donation certificate	Complies__ Does not comply__Not applicable__	
b). The origin of the canine is by purchase.	Support document of the purchase.	Complies__ Does not comply__Not applicable__	
c). The origin of the canine is by breeding.	Support document of the purchase.	Complies__ Does not comply__Not applicable__	
d). Otra modalidad de adquisición.	Support document of the purchase.	Complies__ Does not comply__Not applicable__	
c). Documentary support of the training	Selection document.	Complies__ Does not comply__Not applicable__	
	Training stage follow-up document 15 days.	Complies__ Does not comply__Not applicable__	
	Training stage follow-up document 45 days.	Complies__ Does not comply__Not applicable__	
	Canine fitness document signed by canine guide, instructor or dog groomer.	Complies__ Does not comply__Not applicable__	
	Technical committee document where the decision to discharge the canine is made.	Complies__ Does not comply__Not applicable__	
	Photographs: front, left, right and general side of the canine.	Complies__ Does not comply__Not applicable__	
d). Medical-veterinary documentary supports.	Vaccination card.	Complies__ Does not comply__Not applicable__	
	Health certificate.	Complies__ Does not comply__Not applicable__	

Condition to evaluate	Rubric	Scale	Observations
d). Medical-veterinary documentary supports.	Clinic history.	Complies__ Does not comply__Not applicable__	
	CV.	Complies__ Does not comply__Not applicable__	
	Specialized exams (hip x-ray, brucela, leptospira, blood count, stool).	Complies__ Does not comply__Not applicable__	
	Non-contractual policy (if the law requires it)	Complies__ Does not comply__Not applicable__	

Section 3: Canine sanitary background

The evaluation of this component is carried out only by a veterinary doctor who diagnoses giving a rating of 1 to 3 when 1 is the lowest rating and three the highest rating.

Condition to evaluate	Rubric	Scale	Observations
a). General state of health of the canine.	Breed standard	1___2___3___	
	Conformation and poise		
	Phenotype		
	joints		
	Body condition		
	Denture (age)		
	Sense organs		
	Nervous system		
	Locomotor system		
	Respiratory system		
	Cardiovascular system		
	Digestive system		
	Urinary system		
	Reproductive system		
	Skin and annexes		
	hip XRay:		
	auricular pavilion		
	Ears		
	Emotional state		

Section 4: Basic training test (The test will be presented without tampering the strap or leash)

This component applies to all types of work, searching for people in collapsed structures is accepted. This test also applies to certify canines in the public relations.

Condition to evaluate	Rubric	Scale	Observations
a). Basic training	Walks beside the guide, keeps and stays next to the guide.	Complies__ Does not comply__ Not applicable__	
	Take orders to sit and maintain this behavior	Complies__ Does not comply__ Not applicable__	
	Take orders to lie down and maintain this behavior	Complies__ Does not comply__ Not applicable__	
	Return to the guide's call	Complies__ Does not comply__ Not applicable__	
	Allows third-party manipulation	Complies__ Does not comply__ Not applicable__	

Section 5: Technical sequence to assess the canine's suitability in detecting substances

This test will allow evaluating the degree of registration, response, ability to discriminate, autonomy, and adaptation of the canine.

The evaluation as far as possible should be carried out in the operational area where the K-9 team provides the service, executing tests in areas and media that the canine normally registers, locating the material under detection at different levels, depths and quantities, according to the canine specialty.

Condition to evaluate	Rubric	Scale	Observations
a). Canine fitness during registration	Respond to search or registration order.	Complies__ Does not comply__Not applicable__	
	Maintains the intensity and pattern of continuous recording, for 20 minutes.	Complies__ Does not comply__Not applicable__	

Condition to evaluate	Rubric	Scale	Observations
	It alerts or has evident changes in behavior when perceiving the source of the material, object of detection.	Complies__ Does not comply__Not applicable__	
	It maintains permanence in the source of the material, object of detection.	Complies__ Does not comply__Not applicable__	
	It has the ability to perform registration without a strap.	Complies__ Does not comply__Not applicable__	
	It has the capacity to carry out registration with a strap	Complies__ Does not comply__Not applicable__	
	Overcomes stimulus control in odor discrimination Balls, pot, food, loud noise, threat, caress, others.	Complies__ Does not comply__Not applicable__	
	Shows optimal physical condition during registration	Complies__ Does not comply__Not applicable__	
	It is confident on stage.	Complies__ Does not comply__Not applicable__	
	Registration and response by the canine is autonomous	Complies__ Does not comply__Not applicable__	

5.1 Type of response

In explosive detecting canines, the canine can remain seated, lying down or standing. In the case of canines looking for people in collapsed structures, the response will only be to bark. For the other types of work, the canine can give any of the responses described in the following table:

The canine explosive substances detector can only respond when perceiving the material, object of detection by sitting, lying down, or standing.

Condition to evaluate	Rubric	Scale	Observations
a). Identifiable response when locating the object of detection.	Seated	Complies__ Does not comply__ Not applicable__	
	Lying	Complies__ Does not comply__ Not applicable__	
	Standing	Complies__ Does not comply__ Not applicable__	

Condition to evaluate	Rubric	Scale	Observations
	Scrapes	Complies__ Does not comply__ Not applicable__	
	Barks	Complies__ Does not comply__ Not applicable__	

Section 5.2 Discrimination of substances subject to detection

It is verified that if the canine identifies the basic materials to be detected in each specialty, the point must be filled in according to the canine to be evaluated (explosives, narcotics ...)

5.2.1 Detection of explosives

Condition to evaluate	Rubric	Scale	Observations
a). Ability to discriminate odors derived from explosives. Rural___Uban__	gunpowder	Complies__ Does not comply__ Not applicable__	
	RDX	Complies__ Does not comply__ Not applicable__	
	TNT	Complies__ Does not comply__ Not applicable__	
	PENT	Complies__ Does not comply__ Not applicable__	
	AMMONIUM NITRATE	Complies__ Does not comply__ Not applicable__	

5.2.2 Detection of narcotics

Condition to evaluate	Rubric	Scale	Observations
b). Ability to discriminate narcotic-derived odors.	Cocaine	Complies__ Does not comply__ Not applicable__	
	Marijuana	Complies__ Does not comply__ Not applicable__	
	Heroin	Complies__ Does not comply__ Not applicable__	
	Synthetic drugs	Complies__ Does not comply__ Not applicable__	

5.2.3 Detection of wildlife

Condition to evaluate	Rubric	Scale	Observations
c). Capacidad para discriminar olores derivados de fauna silvestre	Mammals	Complies__ Does not comply__ Not applicable__	
	Amphibians	Complies__ Does not comply__ Not applicable__	
	Birds	Complies__ Does not comply__ Not applicable__	
	Reptiles	Complies__ Does not comply__ Not applicable__	

5.2.4 Detection of human remains

Condition to evaluate	Rubric	Scale	Observations
d). Ability to discriminate odors derived from human remains.	Human bone remains	Complies__ Does not comply__ Not applicable__	
	Soft tissue and blood on hard surfaces	Complies__ Does not comply__ Not applicable__	
	Soft tissue and blood on soft surfaces	Complies__ Does not comply__ Not applicable__	

5.2.5 Trace of human beings

Condition to evaluate	Rubric	Scale	Observations
e). Ability to track and detect human beings.	Traces odorous footprints of humans on hard surfaces	Complies__ Does not comply__ Not applicable__	
	Traces human odor traces on soft surfaces	Complies__ Does not comply__ Not applicable__	
	Get to the source where a human being is	Complies__ Does not comply__ Not applicable__	

5.2.6 Detection of human beings under collapsed structures

Condition to evaluate	Rubric	Scale	Observations
f). Ability to detect humans under collapsed structures	Autonomy to register at least 50 meters in collapsed natural structures.	Complies__ Does not comply__ Not applicable__	
	Autonomy to register at least 50 meters in collapsed structures, (buildings)	Complies__ Does not comply__ Not applicable__	
	Barking alert	Complies__ Does not comply__ Not applicable__	

5.2.7 Hydrocarbon detection

Condition to evaluate	Rubric	Scale	Observations
g). Ability to discriminate odors derived from hydrocarbons	Gasoline	Complies__ Does not comply__ Not applicable__	
	Diesel	Complies__ Does not comply__ Not applicable__	
	Naphtha	Complies__ Does not comply__ Not applicable__	

5.2.8 Money detection

Condition to evaluate	Rubric	Scale	Observations
h). Ability to discriminate odors derived from money	Dollars	Complies__ Does not comply__ Not applicable__	
	Euros	Complies__ Does not comply__ Not applicable__	
	Pesos	Complies__ Does not comply__ Not applicable__	

5.2.9 Tobacco and liquor detection

Condition to evaluate	Rubric	Scale	Observations
i). Ability to discriminate odors derived from tobacco and liquor.	Tobacco or cigarette derivatives	Complies__ Does not comply__ Not applicable__	
	Liquor	Complies__ Does not comply__ Not applicable__	

5.2.10 Basic test for surveillance, security and defense canines

Condition to evaluate	Rubric	Scale	Observations
j). Ability to carry out surveillance, security and defense activities.	Stare at the stranger's threat	Complies__ Does not comply__ Not applicable__	
	Barking alert to stranger's Threat.	Complies__ Does not comply__ Not applicable__	
	Defend the guide against aggression from a stranger.	Complies__ Does not comply__ Not applicable__	
	Make a suit or sleeve bite.	Complies__ Does not comply__ Not applicable__	
	It has the ability to discriminate between the possible aggressor and the sleeve or the bite suit.	Complies__ Does not comply__ Not applicable__	
	It returns to calm and allows contact of the stranger in the absence of aggression or threat.	Complies__ Does not comply__ Not applicable__	
	Show resilience, security and braveness	Complies__ Does not comply__ Not applicable__	

Section 6: Basic test for guides

Condition to evaluate	Rubric	Scale	Observations
j). Ability to carry out surveillance, security and defense activities.	Hygienic condition of the canine presented for the test (teeth, hair, ears, nails)	Complies__ Does not comply__ Not applicable__	
	Elements for the service (ball or other, leash, collar).	Complies__ Does not comply__ Not applicable__	
	Assessment of the scenario before registration (need to register, risks, patterns, start and end points of registration).	Complies__ Does not comply__ Not applicable__	
	Scraper handling (guarantees canine autonomy during registration and ability to guide the canine).	Complies__ Does not comply__ Not applicable__	
	Knowledge of canine behaviors related to detection (behavior changes, alerts, sniffing, sitting, others).	Complies__ Does not comply__ Not applicable__	
	Knowledge of animal protection standards (Law 1774 of 2016, Law 84 of 1989, universal declaration of animal rights, Law 1801 of July 29, 2016).	Complies__ Does not comply__ Not applicable__	
	Knowledge of the operating procedure for canines (guide for the provision of the police service with canines): from 70 to 85%.	Complies__ Does not comply__ Not applicable__	
	Validity of certification as a canine guide	Complies__ Does not comply__ Not applicable__	

Section 7: signature of personnel responsible for the evaluation

Names and surnames	ID #	Position	Signature
		Canine instructor or trainer	
		Veterinarian	
		Canine guide	
		Warehouse Manager	
		Head or commander of the unit	

Note: All the material attached to this evaluation must rest with the respective signature and post-signature of the appropriate person.
To certify canines, it is essential that the canine meets all the requirements according to the training specialty.
It is recommended to support the evaluation with technological means of video and photographs as evidence of the activity.
When completing the format, the fields must be filled according to the specialty of the canine.

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