

Leveraging analytical chemistry and advanced flow visualization for the identification of trace levels of threat material

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Abstract

Due to the ease of material procurement and device development, the use of improvised explosive devices (IEDs) and homemade explosive devices (HMEs) is becoming a prominent focus of explosive mitigation. To address this, sensor technology is often employed by the warfighter to rapidly identify explosive threats and evade incident. Most commonly, explosive detection canines (EDCs) are utilized as sensors and trained to the odor of bulk levels of explosives for detection tasks. However, the challenge for the EDC is to detect trace amounts of the trained odor, as the containment system for the device may limit the amount of odor that is available to the canine. Leveraging analytical chemistry, the amount of odor coming from the improvised device can be measured to better inform canine training to trace levels of threat materials when they are enclosed in a containment system.

Volatile Organic Compound (VOC) Collection

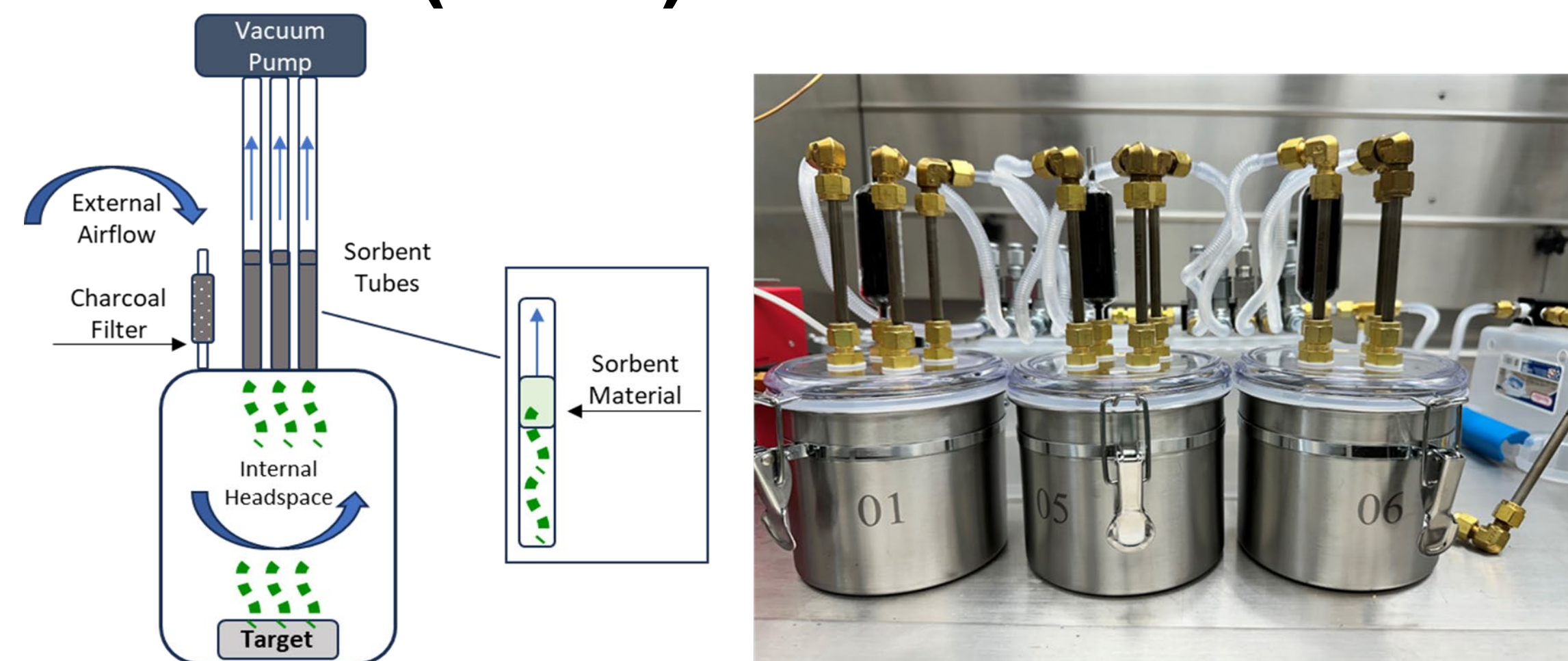


Figure 1: Headspace collection configuration

Headspace volatile organic compounds (VOCs) are collected by placing the target material inside of a sealed canister. A vacuum pump allows VOCs to be pulled onto sorbent packed tubes for subsequent analysis.

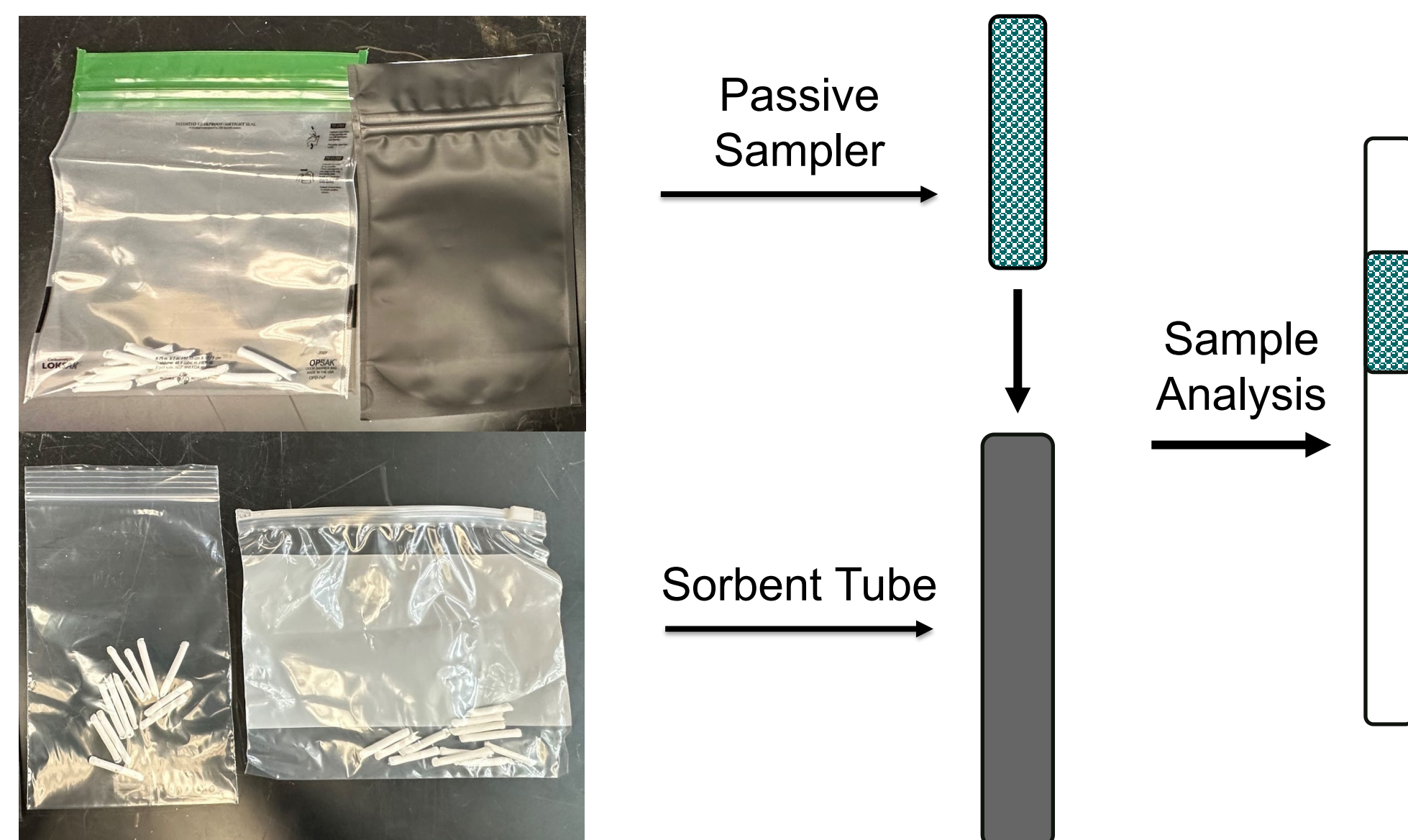


Figure 2: Passive sampling collection configuration

Passive sampler with a sleeve like barrier containing sorbent material (i.e., TENAX) is placed within a containment system. Environmental VOCs are collected passively through the barrier and adsorb onto the sorbent material. Upon completion of collection, the passive sampler is placed inside of a hollow sorbent tube for analysis.



Figure 3: VOCs thermally desorbed onto LECO Pegasus BT 4D GCxGC TOF/MS

Sorbent tubes from VOC collection are loaded onto a PerkinElmer thermal desorber for analysis by GCxGC TOF/MS

GCxGC TOF Data

Chemical evaluation of commonly used canine training aid containment bags indicates these systems are deficient in preventing environmental odors from penetrating the barrier, which can lead to contamination of the contained materials. This can also allow for the odor (s) of the contained material to move into the external environment, potentially contaminating other materials in the vicinity of the system.

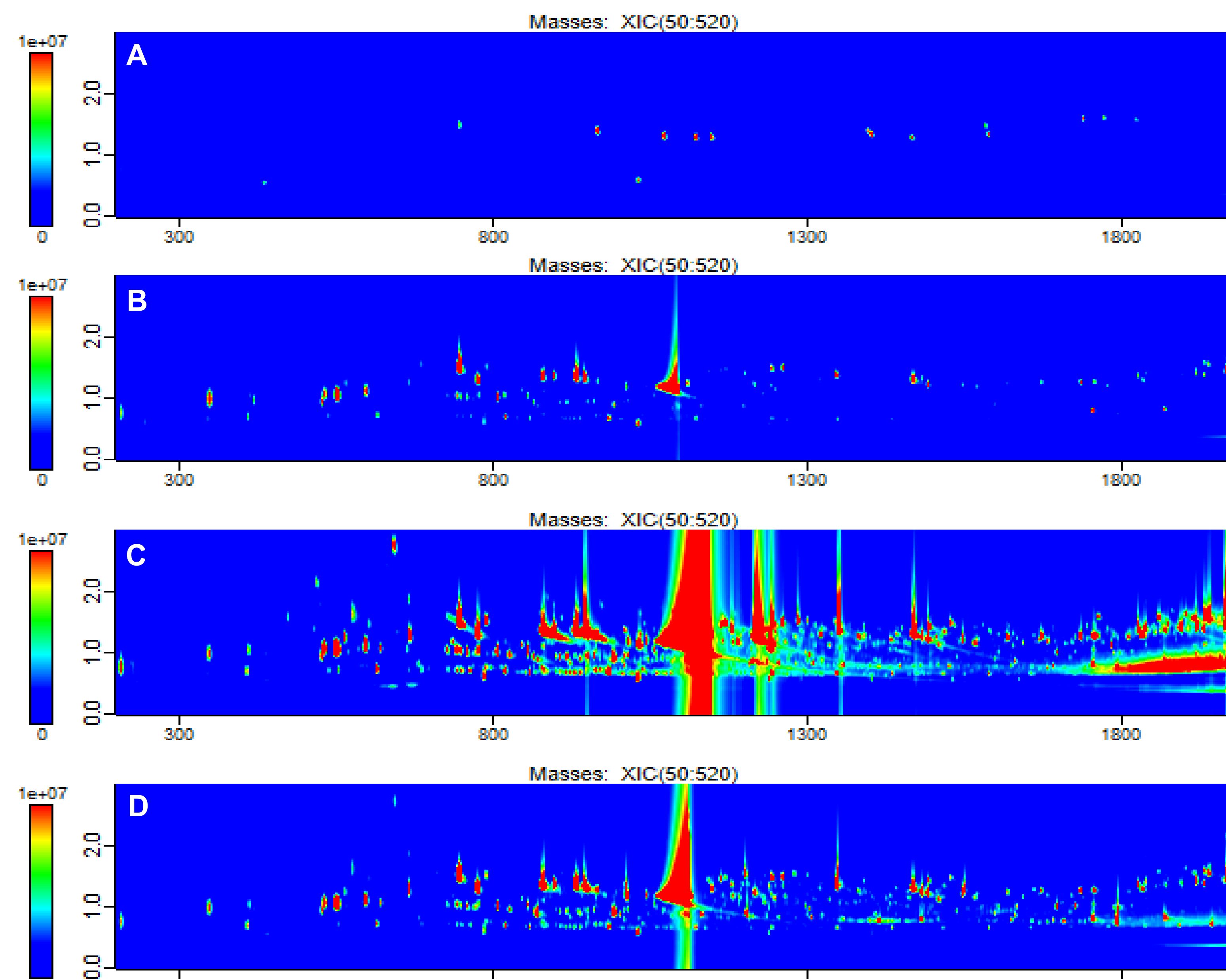


Figure 4: A) 50 ng Explosive standard mix, B) Twenty-four-hour environmental collection (air), C) Two-week passive collection of canvas training aid bag, D) Two-week passive collection of a nylon training aid bag.

Flow Visualization

Schlieren imaging enables the visualization of odors and vapors in the air and ultimately informs best practices for canine training and trace sampling in the field. Seeing how vapors from HMEs and IEDs leak out of various objects helps identify the best approaches for sampling and detecting these threats. Using an anatomically-correct artificial dog nose and schlieren imaging, we show how the dog is an *active* aerodynamic sampling system, utilizing fluid dynamics to increase its ability to sample vapors and aerosols from large distances. Additionally, a new Background Oriented Schlieren (BOS) system was recently developed that enables large scale visualization of how the human thermal plume interacts with the environment and has interesting and important impacts on the nature of odor plume dynamics around the human body. Laser light sheet flow visualization combined with high-speed video capture allows for a qualitative visualization of leak locations in containment devices. Fluid dynamics govern the transport of trace vapors and particulate, so these lessons learned apply not only to HMEs and IEDs, but also chemical and biological threats.

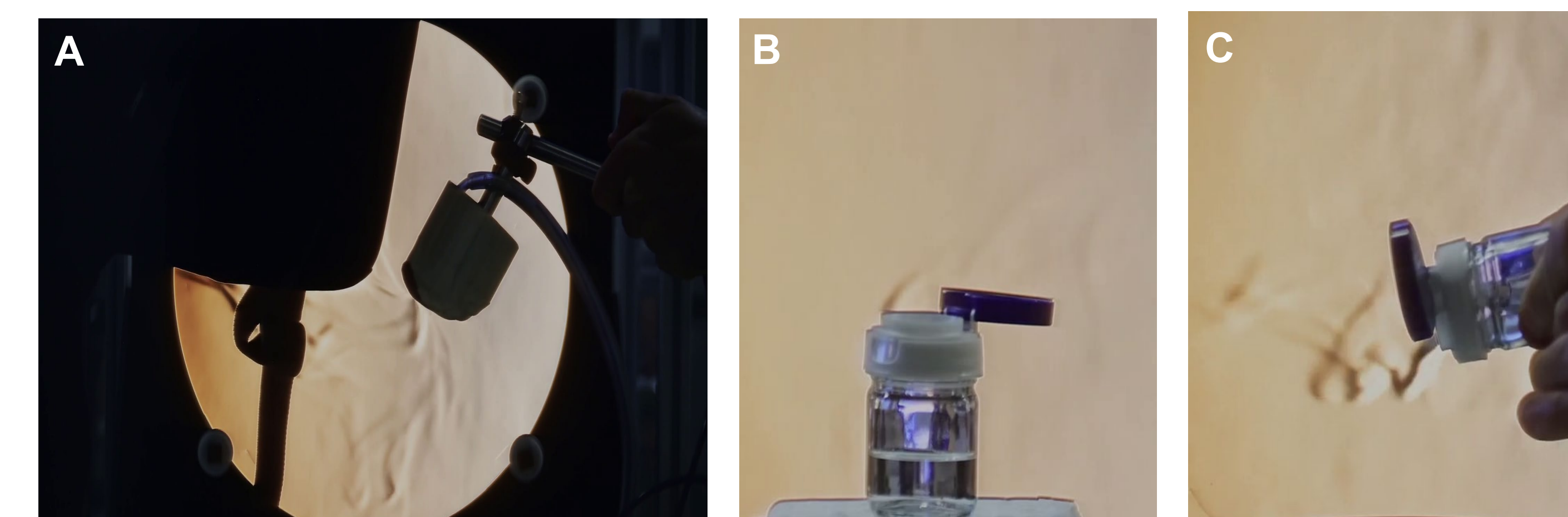


Figure 5: Schlieren imaging of acetone vapor movement

A) Backpack with artificial dog nose sniffing, B-C) Acetone vapor movement from a Training Aid Delivery Device (TADD®)

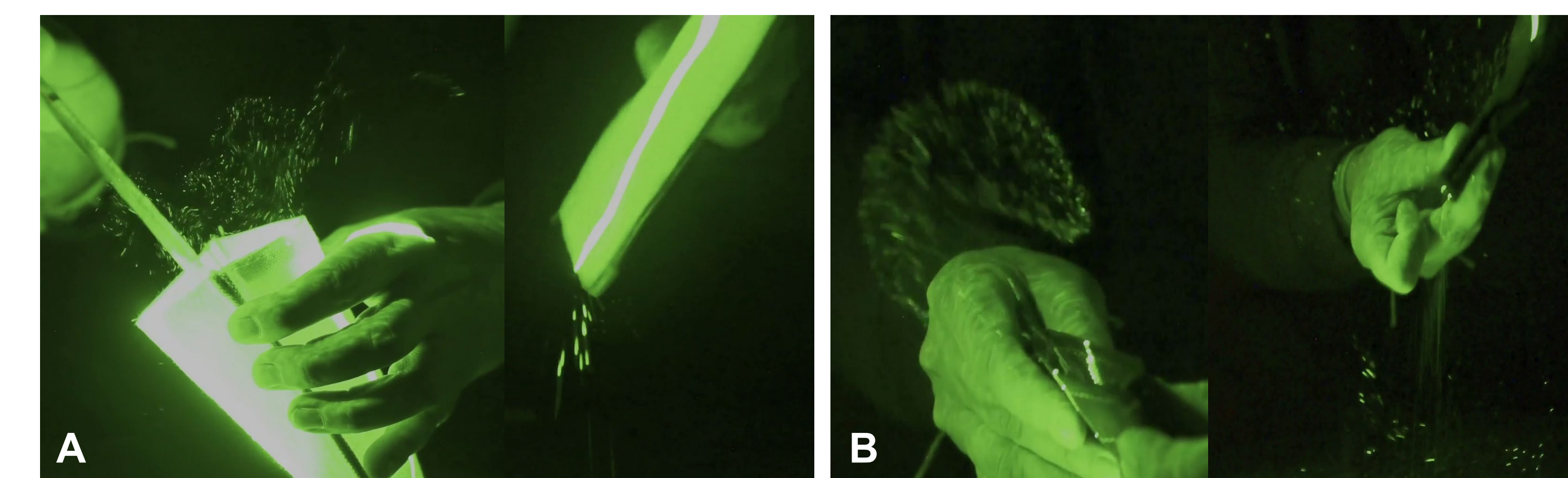


Figure 6: Laser sheet flow visualization of particle movement

A) Particulate movement from canvas training aid bag, B) Particulate movement from a nylon training aid bag

Summary and Future Directions

Analytical techniques are employed to confirm the ability of a system to contain odor and how different systems vary in their level and quality of containment. This information not only allows for a more comprehensive understanding of containment systems and how they may be used to conceal illicit threat materials; but also, in how the quality of a system may cause or prevent contamination of canine training aid materials. Laser and schlieren imaging provide a visual comprehension of vapor and particulate movement from various forms of containment systems. These visualization techniques boost the understanding of odor movement, allowing for a more informed approach to canine training. This work can equip scientists and working dog operators with a bolstered comprehension of odor detection, both on a technical and operational level. Future experimentation will aim to evaluate the range of commonly utilized containment systems and further quantify the amount of vapor and particulate movement in relation to each system.

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