JOURNAL OF FORENSIC SCIENCES

J Forensic Sci, November 2009, Vol. 54, No. 6
doi: 10.1111/j.1556-4029.2009.01153.x
Available online at: interscience.wiley.com

Davia T. Hudson,[1] *Ph.D.; Allison M. Curran,*[1] *Ph.D.; and Kenneth G. Furton,*[1] *Ph.D.*

The Stability of Collected Human Scent Under Various Environmental Conditions*,†

ABSTRACT: Human scent evidence collected from objects at a crime scene is used for scent discrimination with specially trained canines. Storage of the scent evidence is usually required yet no optimized storage protocol has been determined. Storage containers including glass, polyethylene, and aluminized pouches were evaluated to determine the optimal medium for storing human scent evidence of which glass was determined to be the optimal storage matrix. Hand odor samples were collected on three different sorbent materials, sealed in glass vials and subjected to different storage environments including room temperature, −80°C conditions, dark storage, and UVA/UVB light exposure over a 7-week period. Volatile organic compounds (VOCs) in the headspace of the samples were extracted and identified using solid-phase micro-extraction–gas chromatography/mass spectrometry (SPME–GC/MS). Three-dimensional covariance mapping showed that glass containers subjected to minimal UVA/UVB light exposure provide the most stable environment for stored human scent samples.

KEYWORDS: forensic science, forensic chemistry, human scent, volatile organic compounds, solid-phase micro-extraction, gas chromatography–mass spectrometry, storage

For over a century, canines have been successfully used in human scent identification in many European countries, in particular, the Netherlands, Poland, Belgium, Germany, and Hungary. Human scent identification line-ups establish an association between a suspect and an object or location based on canines matching human scent collected from a crime scene to scent collected from the hands of a suspect. This identification is based on the theory that every human has a unique odor and canines have the ability to discriminate between these odors (1).

The scent identification line-up is a controversial type of dog scent evidence presented in courts of law (2). Scent identification line-ups represent a relatively new evidentiary tool in the United States. The introduction of human scent evidence has been challenged in court due to the limited scientific research in this field (3–5). Due to the variability with which scent evidence is collected and analyzed across different agencies, such evidence comes under much scrutiny (4,5). For this evidence to be accepted in a United States court of law, it must satisfy the Kelly-Frye, Daubert, or Federal Rules of Evidence depending on if it is a federal offence, the crime committed, and the state in which the case is being tried. In a recent US court, *People of the State of California versus Benigo Salcido*, human scent evidence evaluated by canines was challenged. Some of the issues raised included the uniqueness of human scent, survivability of human scent, and whether canines can be trained to discriminate between scents (6). Numerous testimonies were presented by expert witnesses resulting in the court ruling that human scent evidence can be admissible if: "the person performing the technique used the correct scientific procedures, the training and experience of the dog and dog handler prove them to be proficient, and the methods used by the dog handler in the case are reliable" (6). This case demonstrates the need for the use of robust scientific procedures to produce reliable, reproducible scent evidence that will be admissible in a United States court of law.

Human scent samples for canine use are usually collected utilizing either a direct collection procedure or an indirect collection procedure. The direct collection method involves collecting an article of evidence from the scene of the crime, whereas the indirect method involves the use of a sorbent material to collect the scent from the article of evidence (7). The sorbent material that is employed is dependent on the protocol of the specific country, although cotton-based sorbents are usually used in Europe (8). A suspect is often not immediately identified so the storage of samples is required. Western European countries are currently storing their human scent samples in rooms which are at a constant temperature and are exposed to little or no daylight (8). In Asia, China has recently reported the development of a "scent bank" where scent samples collected on various sorbents are stored at −18°C (9,10).

Solid-phase micro-extraction–gas chromatography/mass spectrometry (SPME–GC/MS) is an analytical technique which has been used for the extraction of volatile organic compounds (VOCs) which are present in the headspace of various forensic samples such as drugs, explosives, and human scent. SPME–GC/MS has proven to be a viable technique for the extraction, separation, and identification of the compounds which are present in the headspace of scent samples (11–16). The headspace of scent samples collected and aged can be distinguished chromatographically based on a combination of the relative peak area ratios of the common compounds present in these samples. Due to the volatile nature of scent samples, it is important to determine the optimal materials and procedures for the collection and storage of human scent (14). The purpose of this study is to evaluate a variety of storage container types and to determine the effects of various storage conditions on collected human scent samples.

[1]Department of Chemistry and Biochemistry, International Forensic Research Institute, Florida International University, Miami, FL 33199.

*Support in the form of a grant was obtained from the Netherlands National Police.

†Presented in a poster form at the 58th Annual Meeting of the American Academy of Forensic Sciences in Seattle, WA, February 20–25, 2006.

Received 30 June 2008; and in revised form 25 Oct. 2008; accepted 26 Oct. 2008.

Materials and Methods

This study was approved by the Florida International University Committee on Human Subjects (Institutional Review Board).

Materials

Sorbent materials used were DUKAL brand, sterile, 2 × 2 inch, 8 ply, gauze pads (DUKAL Corporation, Syosset, NY), Kings Cotton, non-sterile, 2 × 2 inch sorbent material (Seafarma, the Netherlands) and Johnson and Johnson brand, sterile, 2 × 2 inch gauze pads (Johnson and Johnson Consumer Products Company, China). The extraction solvents for the supercritical fluid extraction were supercritical grade carbon dioxide (Air Products, Allentown, PA) and HPLC grade methanol (Fisher Scientific, Pittsburgh, PA). The heat sealer utilized was a Maxi Seal electric heat sealer (Premium Balloon Accessories, Taiwan).

Different types of containers evaluated as possible storage containers for human scent included: Ziploc, Freezer Guard Seal, Pint Size, 7.0 × 5.25 inch (SC Johnson & Sons Inc., Racine, WI). Kapak Heavy Duty SealPAK Pouches, PET//LLDPE, 4.5 mL thick, 6.5 × 8 inch (Kapak Corporation, Minneapolis, MN), Kapak Aluminized Pouches, tri-layer polymer chemistry featuring an aluminum film, 6.5 × 8 inch (Kapak Corporation), polyethylene pouches, 3 × 3 inch, 2 mL thick (Veripak, Atlanta, GA).

The containers used to hold the sorbent materials for storage were 10-mL glass, clear, screw top vials with PTFE/Silicone septa (SUPELCO, Bellefonte, PA). The soap used for hand washing was Natural, Clear Olive Oil Soap from Life of the Party (North Brunswick, NJ). The SPME fibers used for the headspace extractions were 50/30 μm divinylbenzene/carboxen/polydimethylsiloxane (SUPELCO, Bellefonte, PA).

The temperature and the humidity of the storage conditions were monitored using Thermochron I-Buttons (MAXIM, Dallas, TX). Storage containers used were glass aquarium tanks (All Glass Aquarium, WI) enclosed with aluminum foil (Reynolds Consumer Products Richmond, VA). The light source used was a UVA/UVB reptile light (Energy Savers Unlimited, CA). The −80°C freezer used was a VWR brand (Revco Scientific Inc., Asheville, NC).

SFE Pre-Treatment of Gauze

The equipment used was an ISCO Model 260D Syringe Pump with an SFX 2–10 Supercritical Fluid Extractor. The SFE conditions used included direct spiking of 1000 μL of methanol into the 10 mL extractor vessel, 30 min static extraction followed by a 10 min dynamic extraction at 1.5 mL/min and 4500 psi. The vessel was maintained at 130°C (11).

Evaluation of Different Storage Containers

SFE pre-treated Dukal gauze was sealed into five types of storage containers which include: 10-mL glass, clear, screw top vials with PTFE/Silicone septa, Ziploc, Freezer Guard Seal, Pint Size bags, KPAK Heavy Duty SealPAK Pouches, KPAK Aluminized Pouches, and polyethylene pouches. A heat sealer was used to seal both the KPAK Heavy Duty SealPak and Aluminized pouches as well as the polyethylene, whereas the Ziploc, Freezer Guard bags were sealed using the zipper at the top of the bag. These storage containers were evaluated in triplicate at each of the different time intervals, including 1-, 2-, and 5-week periods. At the end of the time periods each piece of gauze was removed from its respective storage material and placed back into its original vial using tweezers previously rinsed with a bleach solution and dried. Each stored gauze pad was then re-evaluated using a SPME–GC/MS method.

Hand Sampling Procedure

Five hand odor samples were collected per day from six subjects. Samples were collected from each subject over four consecutive days resulting in a total of 20 samples per subject. Subjects were required to wash hands and forearms with clear Olive Oil Soap for 30 sec, rinse with water for 2 min, air dry for 4 min, then rub the palms of hands over forearms for 5 min. Subjects then sampled themselves by holding the pre-treated 2 × 2 absorbent material (DUKAL brand gauze pads, Kings Cotton absorbent material, and Johnson and Johnson brand) between the palms of the hands for 10 min. The sample was then placed back inside the 10-mL glass vial and sealed by the subjects. This sampling procedure was previously determined to be a viable collection technique to obtain individual human scent profiles from the hands (8,13,16), and olive oil-based, fragrance free soap has been shown previously not to contain any previously reported human scent compounds (14).

Storage of Scent Samples

The collected hand odor samples were subjected to four different environmental conditions: room temperature, −80°C temperature, dark, and UVA/UVB light. Samples stored at room temperature were allowed to stand in an open environment over the 7-week period. These samples were subjected to 10 h of fluorescent lighting of *c.* 300–500 lux and 14 h of darkness. The room temperature was controlled to within ± 1°C with an average temperature of 20°C and an average relative humidity of 56 ± 6%. Samples stored at −80°C were maintained at a temperature of −80 ± 2°C. Once removed from this condition for analysis, samples were allowed to equilibrate to ambient condition for 1.5 h before being subjected to a 21 h SPME extraction.

The container used for the dark storage environment was completely enclosed with aluminum foil to prevent the entry of light. The average temperature and relative humidity in this container was 19 ± 4°C and 71 ± 6%, respectively. The container used for storage of the samples subjected to UVA/UVB light was only partially enclosed with aluminum foil with an opening at the top for the positioning of a 500 lux UVA/UVB light source. The 10-mL glass vials which were used for the storage of the scent samples, offer no protection against the transmission of UV light. The samples which were stored in this condition were constantly exposed to the UVA/UVB light source for the duration of the storage period. The average temperature and relative humidity in this container was 22 ± 2°C and 63 ± 3%, respectively.

Environmental controls were prepared by storing each of the three sorbent material types used for collection of hand odor samples in all four environmental conditions and monitored over the time period. The materials were all pre-cleaned using the SFE method which was previously discussed. Four of the five samples collected on each sorbent material were stored in each environmental condition and at the specific time period (week 1, week 3, week 5, and week 7) one was removed and analyzed using SPME–GC/MS (the fifth sample was used for week 0 analysis).

SPME–GC/MS Procedure

The VOCs from the headspace of the vials containing the absorbent material were extracted using 50/30 μm DVB/CAR/PDMS fibers (13). Single headspace extractions of each vial from each of the storage conditions were performed at room temperature for 21 h. The instrumentation used for the separation and analysis of the analytes was an Agilent 6890 GC/5973 MSD with a 0.25 mm × 30 m HP5-MS column which had a 0.25 μm phase film thickness. Helium carrier gas was maintained at a flow rate of 1.0 mL/min. The initial GC oven temperature of 40°C was held for 5 min, followed by a temperature ramp of 10°C per minute to a final temperature of 250°C which was held for 2 min. The mass spectrometer transfer line was maintained at 280°C and the source temperature was 230°C. Mass spectra were repeatedly scanned from 39–300 m/z. Mass spectra data from 2000 to 6600 scans were exported into comma separated values (CSV) format files using the Agilent Chemstation 3D-Export option. The CSV files were transferred into Microsoft Excel (Microsoft Inc.) where matrix manipulations were performed using an in-house written software running on a PC.

Statistical Evaluation

Three-dimensional covariance mapping was used to compare the VOCs present in the week 0 hand odor samples to the VOCs in the aged hand odor samples (week 1, 3, 5, and 7). Utilization of this technique demonstrates whether or not two hand odor samples collected from the same individual remain unchanged over a storage period as it provides an assessment of origin based on pattern recognition and comparison. Comparisons of covariance maps computed from GC/MS data have previously been used to provide a fingerprint for complex samples such as ignitable liquids (17). Three-dimensional covariance mapping was used for the analysis of the data by using mass spectrometry software to export a data matrix comprised of the individual ion abundances for each mass-to-charge ratio for the mass spectra data from scan 2000–6600 of the chromatographic analysis. The covariance matrix is computed by pre-multiplying the exported matrix by its transpose (the rows of the original sample become columns and vice versa). The computed matrix is normalized and two matrices are compared analytically by calculating a distance, *D*. *D* is calculated according to the equation below (17):

$$D = \frac{\sum_i \sum_j |z_{N1}(ij) - z_{N2}(ij)|}{2}$$

Z_N represents the covariance matrix which is normalized such that the sum of all matrix elements equal one. The maximum value that can be obtained is 1 and so a similarity index, *S*, based on *D* can also be calculated using the equation below:

$$S = 1 - D$$

The similarity index produces values between 0 and 1; 1 demonstrates similarity while a value of 0 shows total dissimilarity.

Discussion

Evaluation of Different Storage Containers

An optimization of storage container type is an important aspect to determining an optimized storage protocol for human scent evidence. Various types of containment were evaluated to determine if the containment matrixes had any contributions of volatile compounds onto gauze materials which were initially determined to be analytically clean at time zero. Figure 1 shows representative chromatograms produced from storage of pre-treated gauze in glass vials, polyethylene pouches, Ziploc Freezer Guard bags, Aluminized Kapak, and Heavy Duty Kapak pouches for the 5-week period. Table 1 displays the average number of overall compounds detected across the triplicate cotton material samples stored in the various containers at week 1, week 2, and week 5 and also displays the number of previously reported human scent compounds detected. The storage container which contributes the least amount of both overall compounds and those previously reported to be components of human scent onto the pre-treated gauze is the

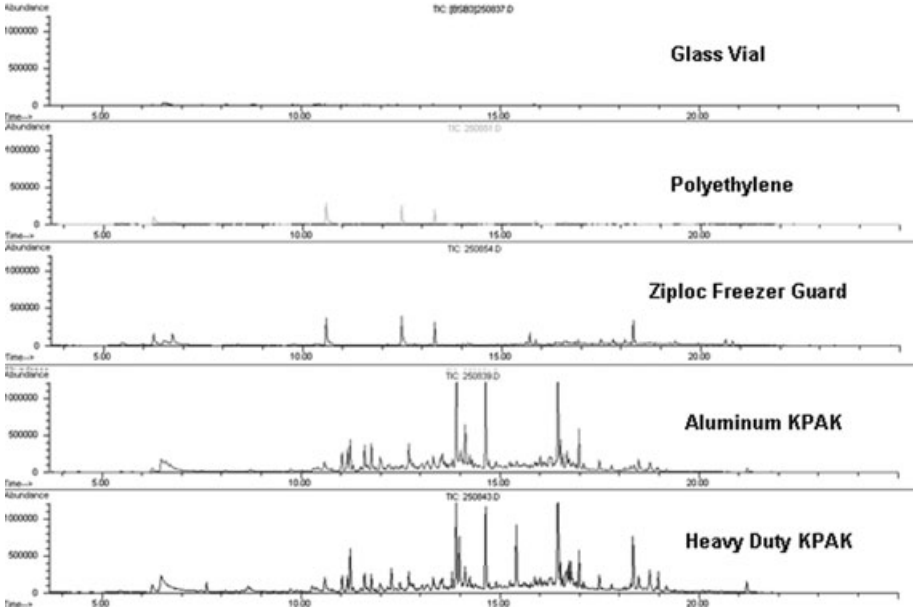

FIG. 1—*Chromatograms showing the effects of storing analytically clean sorbents in various containers for 5 weeks.*

TABLE 1—*Average number of compounds present on analytically clean sorbent materials after storage in different types of containers.*

	Average Number of Compounds			Average Number of Human Compounds		
Storage Container	Week 1	Week 2	Week 5	Week 1	Week 2	Week 5
10-mL glass vial	2	1	5	1	0	1
Polyethylene	19	24	11	6	7	2
Ziplock Freezer Guard	40	19	15	9	3	3
Aluminum KPAK	93	85	88	6	3	2
Heavy Duty KPAK	116	116	107	7	8	6

TABLE 2—*Calculated similarity, S, between hand odor samples collected on different sorbent materials and stored at room temperature over a 7-week period (week 0 vs. weeks 0, 1, 3, 5, and 7).*

Room Temperature			
Time (Weeks)	Dukal	Kings Cotton	Johnson and Johnson
0	1.00	1.00	1.00
1	0.79	0.71	0.74
3	0.59	0.58	0.67
5	0.66	0.52	0.53
7	0.64	0.54	0.49

10-mL glass vial, whereas the material which contributes the most is the Heavy Duty Kapak pouches.

The glass containment evaluated during the storage period displayed the presence of nonane in two of the nine samples, which has been previously reported to be a human odor compound. Four compounds detected in one of the triplicate samples analyzed during week 5 of storage in the glass container were long-chain cyclic alkanes which were present due to SPME fiber degradation after the extended extraction times utilized for analyzing human scent and were not present due to the glass containment. The gauze materials placed inside the polyethylene, Aluminized Kapak, and Heavy Duty Kapak pouches were all sealed utilizing a heat sealer. The compound classes detected in these materials included alkanes, aldehydes, acid-methyl esters, and alcohols. The process of heat sealing may have caused the creation and/or release of many of the compounds detected on the gauze after storage in these matrixes.

In terms of analytical evaluation an increase in the background is a major problem as instruments have limitations in terms of selectivity. Canines, however, depending on their training have demonstrated comparatively enhanced selectivity as they possess the ability to detect targets in the presence of a high background. Although the increase in overall background levels may not pose a problem for canine evaluation of human scent samples the possibility exists that if compounds previously determined to be present in human scent are added to human scent samples through contact with storage materials the scent profile may be altered thus affecting performance of the canines. As glass was determined to be the optimal containment for the gauze collection materials, in the storage environment experiments glass vials were utilized for all subsequent storage of samples.

Storage of Scent Samples

Five hand odor samples were collected per day from six subjects (two subjects per material). Samples were collected from each subject over four consecutive days resulting in a total of 20 samples per subject which were stored in four different environmental conditions. The sorbent materials used were Dukal brand gauze pads, Kings Cotton sorbent material and Johnson and Johnson brand gauze pads. Dukal brand gauze and Kings Cotton are both 100% cotton, whereas the Johnson and Johnson brand gauze is a blend of polyester, rayon, and cellulose.

Environmental controls were monitored across the time period by storing each of the three sorbent material types used for collection of hand odor samples in all four environmental conditions. As previously described in the section above, glass containment provides minimal contribution of previously reported human odor compounds to the stored samples; any detection of nonane was disregarded in this analysis. Storage in the presence of UVA/UVB light did however result in the detection of aldehydes previously reported as being human scent compounds. These compounds were not initially detected in the SFE cleaned gauzes. As this was only observed with the sorbent materials which were stored in the presence of UVA/UVB light, it is being assumed that the UV light may have caused the creation and/or release of the aldehydes detected on the gauze after storage in this condition. The detection of the aldehydes over time was observed mainly on the 100% cotton sorbents. These results suggest that the sorbent materials were being adversely affected by the UVA/UVB light storage. Previous research has shown that materials such as cotton even though they have good resistance to sunlight, degrade with prolonged exposure to ultraviolet light (18).

Room Temperature Storage

Comparisons made utilizing three-dimensional covariance mapping values demonstrated that the scent profiles on all the absorbent materials were changing as the storage period progressed (Table 2). The hand odor samples which were stored on the Dukal brand gauze at room temperature produced a similarity value of 0.64 at the end of the storage period while similarity values of 0.54 and 0.49 were obtained for Kings Cotton and Johnson and Johnson brands, respectively. This showed that Dukal gave the least variation over the 7-week period when compared to the samples stored on the two other sorbent materials. Also, the difference between the similarity values for week 0 and week 1 was greater than the difference between week 5 and week 7. This trend was observed across all three sorbent materials (Table 2). This suggests that the VOCs in the scent samples were changing less as the storage period progressed.

−80°C Storage

Similarity values of 0.64, 0.60, and 0.66 were obtained for Dukal brand, Kings Cotton and Johnson and Johnson brand gauze respectively for the seventh week of storage in −80°C.

Of all the three sorbent materials, Johnson and Johnson brand showed the greatest similarity between the week 0 and the week 7 samples. The Johnson and Johnson gauze also showed a smaller difference between the similarity values for week 5 and 7 when compared to Dukal and Kings Cotton (Table 3).

This shows the 100% cotton materials reacting differently than the Johnson and Johnson gauze in the −80°C storage condition. This can possibly be explained by the characteristic nature of the samples; cotton fibers are hydrophilic and swell in water whereas polyester is hydrophobic and repels water (18,19). Once hand odor samples are collected, it is possible there are small quantities of moisture present on the sorbent material. This could result in the freezing and thawing of the samples during storage and analysis,

TABLE 3—*Calculated similarity, S, between hand odor samples collected on different sorbent materials and stored at −80°C over a 7-week period (week 0 vs. weeks 0, 1, 3, 5, and 7).*

	−80°C		
Time (weeks)	Dukal	Kings Cotton	Johnson and Johnson
0	1.00	1.00	1.00
1	0.65	0.82	0.80
3	0.88	0.92	0.75
5	0.86	0.86	0.72
7	0.64	0.60	0.66

having a greater effect on the 100% cotton sorbent materials more than the Johnson and Johnson brand which is a blend of cotton/rayon and polyester.

Dark Storage

The samples which were stored on Dukal brand gauze in the dark produced a similarity value of 0.67 at week 7 while similarity values of 0.43 and 0.42 were obtained for Kings Cotton and Johnson and Johnson brand, respectively (Table 4). Samples stored in this condition showed a gradual decrease in the similarity values as the storage period progressed. Like the room temperature storage, the differences in the similarity values between the initial weeks (week 0 and 1) were greater than between the final weeks (week 5 and 7) of storage. This trend was observed for all three sorbent materials.

UVA/UVB Light Storage

Hand odor samples subjected to storage in the presence of UVA/UVB light also showed a gradual decrease in the similarity values over the storage period for all absorbent materials investigated (Table 5). The Johnson and Johnson brand gave the greatest change over the 7-week period (7): three-dimensional covariance mapping value of 0.32. Storage in the presence of UVA/UVB light resulted in the detection of methyl esters and aldehydes which were not previously detected in the "fresh" (week 0) hand odor samples. These "new" compounds which were often detected by the third week of storage persisted for the remainder of the storage period. This is similar to what was observed with the environmental controls stored in this condition.

TABLE 4—*Calculated similarity, S, between hand odor samples collected on different sorbent materials and stored in the dark over a 7-week period (week 0 vs. weeks 0, 1, 3, 5, and 7).*

	Dark		
Time (weeks)	Dukal	Kings Cotton	Johnson and Johnson
0	1.00	1.00	1.00
1	0.87	0.53	0.76
3	0.78	0.71	0.70
5	0.72	0.54	0.54
7	0.67	0.43	0.42

TABLE 5—*Calculated similarity, S, between hand odor samples collected on different sorbent materials and stored in the presence of UVA/UVB/ light over a 7-week period (week 0 vs. weeks 0, 1, 3, 5, and 7).*

	UVA/UVB Light		
Time (Weeks)	Dukal	Kings Cotton	Johnson and Johnson
0	1.00	1.00	1.00
1	0.74	0.66	0.58
3	0.71	0.58	0.56
5	0.70	0.71	0.36
7	0.66	0.59	0.32

Also, studies conducted on changes in the lipid composition of fingerprint residue, collected on glass fiber filter paper, have shown that the presence of UV light does produce oxidation reactions resulting in the formation of VOCs such as aldehydes and methyl esters (20). Oxidative degradation of the fatty acid component of sebaceous glands has also been shown to produce aldehydes (21). These are some possible reasons aldehydes and methyl esters were detected but there is no certainty as to whether or not these compounds were created during exposure to UVA/UVB light or they were originally present but not readily released by the sorbent materials. This was however not observed in any of the other storage conditions.

An individual's primary odor compounds have been defined by Curran et al. as the constituents of the odor that are stable over time regardless of diet or environmental conditions (14–16). The compounds which were consistently present in the individual hand odor samples over 4 days of sampling were chosen to be the primary odor compounds and these compounds were monitored over the storage period. The primary odor compounds were determined to be 2-furancarboxaldehyde, phenol, nonanal, and decanal for the hand odor samples collected on the Dukal brand gauze and stored in the presence of UVA/UVB light. The "new compounds" detected after week 3 were benzaldehyde, octanal, undecanal, decanoic acid-methyl ester, and 2-octenal. The hand odor samples collected from a male subject and stored on Kings Cotton in the presence of UVA/UVB light had, as its primary odor compounds, benzyl alcohol, nonanal, decanal, and tetradecane while the "new compounds" detected were benzaldehyde and octanal. For the samples collected from a female subject on Johnson and Johnson brand gauze and stored in UVA/UVB light, the primary odor compounds were found to be nonanal, decanal, undecanal, and dodecanal. Unlike the 100% cotton sorbents, the "new compounds" that were detected and persisted on the Johnson and Johnson brand gauze after week 3 were mainly alkanes such as hexadecane and pentadecane.

Aging Effects

The primary odor compounds only account for a fraction of the overall scent profile (11,14–16). Throughout the storage period, the human VOCs present in the hand odor sample for each of the subjects were monitored via single headspace SPME extractions followed by analysis via GC/MS. Changes in the scent profile whether from the primary odor compounds or additional human compounds in the scent profile were detected by three-dimensional covariance mapping. For all the conditions and sorbent materials monitored, covariance mapping showed that the greatest variation within the scent samples was observed between week 0 and 3 after which the variations between samples decreased (week 3–7) (Tables 2–5). Despite the observed changes in the overall scent profile, the ratios of the monitored primary odor compounds remained consistent (Figs. 2–4).

These results are comparable to an aging study (2 weeks to 6 months) on crime scene objects conducted by Schoon of the Netherlands National Police. The study showed that dogs could faultlessly match odors which were collected on the same day but their performance decreased when instructed to match stored

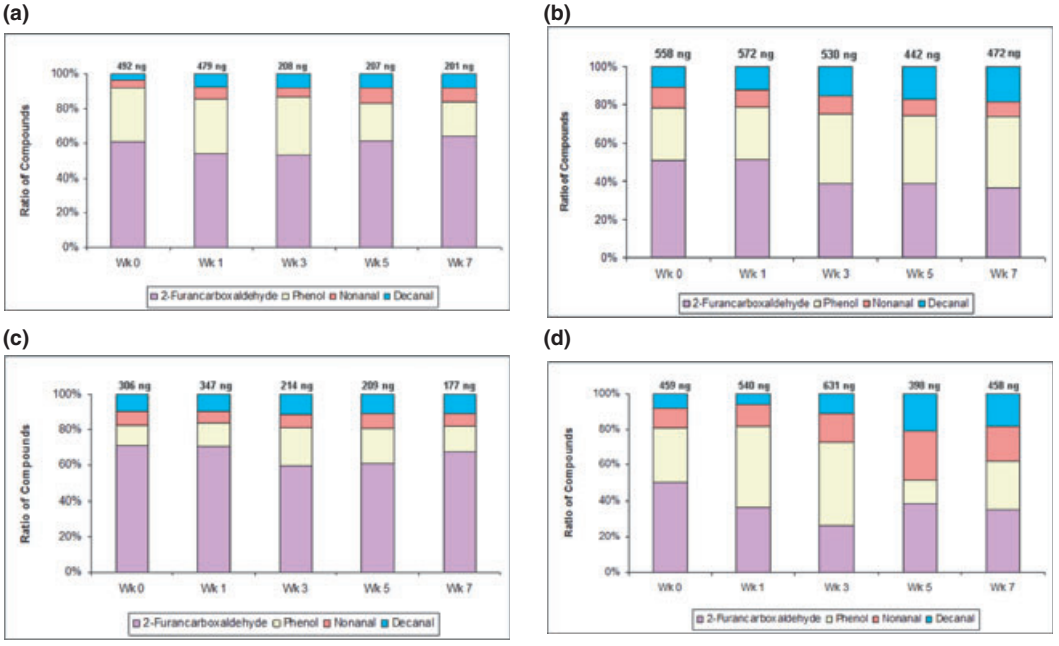

FIG. 2—*Comparison between common VOCs present in hand odor samples collected on Dukal brand gauze from a male subject and stored at (a) room temperature, (b) −80°C, (c) dark, (d) UVA/UVB light.*

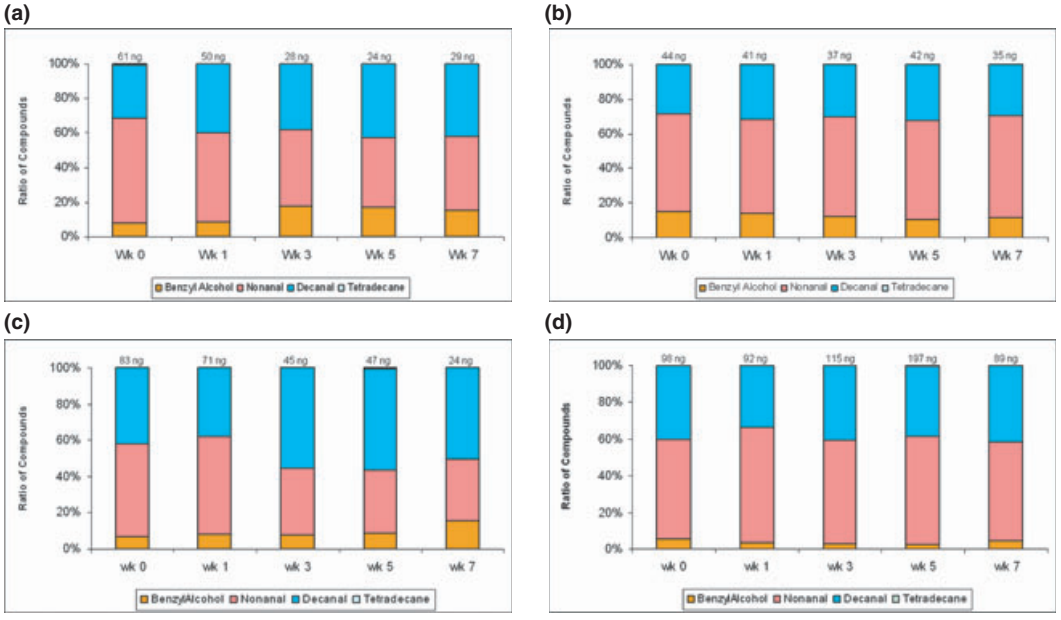

FIG. 3—*Comparison between common VOCs present in hand odor samples collected on Kings Cotton from a female subject and stored at (a) room temperature, (b) −80°C, (c) dark, (d) UVA/UVB light.*

objects to a subject (22). The presence of additional compounds due to storage may mask the primary odor compounds of an individual's scent sample resulting in decreased canine performances when matching aged samples. It is believed that the canines were however still able to make a match as the primary odor compounds are still present in a consistent ratio.

Conclusion

This study of storage containers has demonstrated that when analytically clean cotton materials are stored inside various polymer and aluminized materials a significant amount of compounds are imparted to the cotton material, including compounds previously determined to be present in human scent. Glass has been determined to be the optimal type of storage container for human scent samples as the cotton materials stored in that manner had less overall compounds contributed through the storage method, but also significantly less compounds that have been previously reported to be present in human scent. Glass storage materials are also the storage container used most readily by human scent canine units across Europe (8).

The sorbent materials may have also had an effect on the stored hand odor samples perhaps due to their different chemical compositions. The Dukal brand gauze gave the highest similarity values

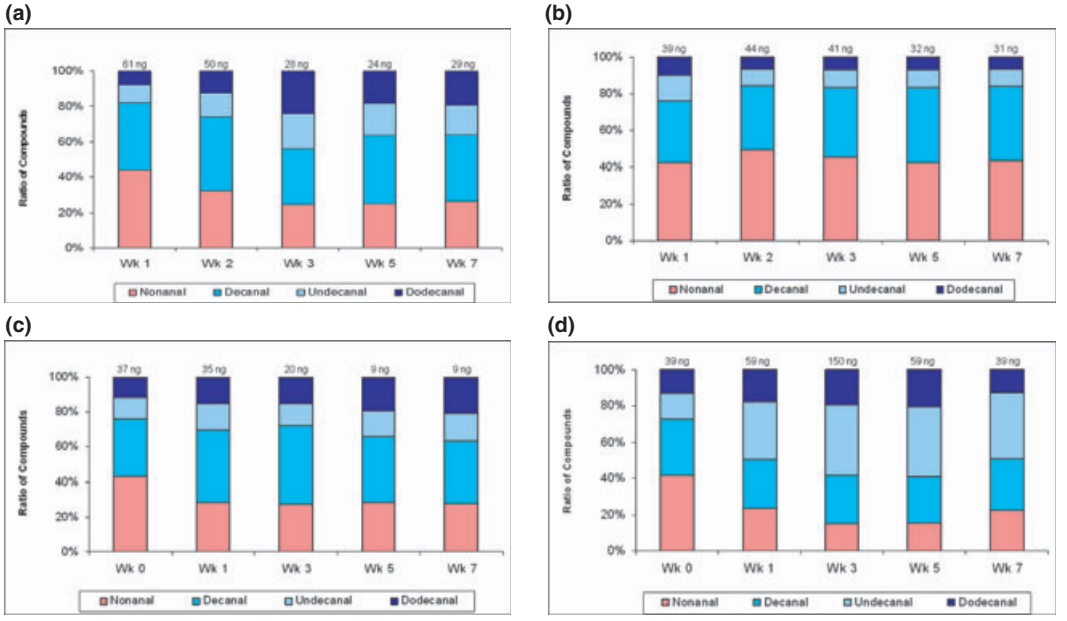

FIG. 4—*Comparison between common VOCs present in hand odor samples collected on Johnson and Johnson brand gauze from a female subject and stored at (a) room temperature, (b) −80°C, (c) dark, (d) UVA/UVB light.*

over the 7-week storage period (7), therefore offering the least variation in all the storage conditions. The Johnson and Johnson brand gauze however, produced the lowest similarity values over the storage period resulting in the most variations for all the conditions. The similarity index also showed a consistent decrease for the Johnson and Johnson compared to the 100% cotton materials. This was likely due to the different fiber chemistries of the sorbent materials. The 100% cotton materials have a more polar backbone and since the majority of the primary odor compounds observed are polar compounds this may have resulted in enhanced collection and retention of compounds compared to the Johnson and Johnson material. The three-dimensional covariance mapping results also showed that the 100% cotton materials did not perform well in the −80°C storage condition as there continued to be great differences in the similarity values in the final weeks of storage (weeks 5 and 7). Whether or not changes using different storage conditions would influence matches by canines was not part of this study and is being evaluated in ongoing studies.

The findings of this study also suggest that for all the environmental conditions studied, the scent profile changed with time with the greatest variations being observed between week 0 and 3 as determined by three-dimensional covariance mapping. The results show that scent samples should not be exposed to excessive amounts of UVA/UVB light as this will result in the detection of a greater number of methyl esters and aldehydes in the headspace of the sample which may alter the human scent profile.

References

1. Stockholm RA, Slavin DL, Kift W. Specialized use of human scent in criminal investigations. Forensic Sci Int 2004;6(3):1–13.
2. Taslitz AE. Does the cold nose know? The unscientific myth of the dog scent lineup. Hastings LJ 1990;42(17):1–179.
3. Mesloh C. Scent as forensic evidence and its relationship to the law enforcement canine [Thesis]. Orlando (FL): Univ. of Central Florida, 2000.
4. *The People, Plaintiff and Respondent vs. Ryan Willis:* Hearing on B160530 Before the Court of Appeal of California, Second Appellate District, Division Two on 115 Cal. App. 4th 379 (2004).
5. *The People, Plaintiff and Respondent vs. Jeffrey Dewayne Mitchell* et al. Hearing on B151026 Before the Court of Appeal of California, Second Appelate District, Division One on 110 Cal. App. 4th 772 (2003).
6. *People of the State of California vs. Benigno Salcido:* Hearing on GA052057 Before the Los Angeles Superior Court on 115 Cal. App. 4th 379 (2005).
7. Eckenrode BA, Ramsey SA, Stockham RA, Van Berkel GJ, Asano KG, Wolf DA. Performance evaluation of the scent transfer unit™ (STU-100) for organic compound collection and release. J Forensic Sci 2006; 51(4):780–9.
8. Schoon A, Haak R. K-9 Suspect discrimination, training and practicing scent identification line-ups. 1st edn. Canada: Detselig Enterprises Ltd, 2002.
9. http://www.english.peopledaily.com.cn/200603/21/eng20060321_252270.html Accessed September 13, 2007.
10. http://www.news.xinhuanet.com/english/2006-03/15/content_4307207.html Accessed September 13, 2007.
11. Curran AM, Rabin SI, Prada PA, Furton KG. Comparison of the volatile organic compounds present in human odor using SPME–GC/MS. J Chem Ecol 2005;31(7):1607–19.
12. Lorenzo N, Wan T, Harper RJ, Hsu YL, Chow M, Rose S, et al. Laboratory and field experiments to identify Canis lupus var. familiaris active odor signature chemicals from drugs, explosives, and humans. Anal Bioanal Chem 2003;376:1212–24.
13. Curran AM, Ramirez CF, Schoon AA, Furton KG. The frequency of occurrence and discriminatory power of compounds found in human scent across a population determined by SPME–GC/MS. J Chromatogr B Analyt Technol Biomed Life Sci 2007;846(1–2):86–97.
14. Curran AM. The analytical determination of the uniqueness and persistence of the volatile components of human scent using optimized collection methods [Dissertation]. Miami (FL): Florida International University, 2005.
15. Schoon GAA, Curran AM, Furton KG. Odor biometrics. In: Li S, editor. Encyclopedia of biometrics. North America: Springer, 2009;1003–8.
16. Curran AM, Prada PA, Furton KG. The differentiation of the volatile organic signatures of individuals through SPME–GC/MS of characteristic human scent compounds. J Forensic Sci. 2010; In press.
17. Sigman ME, Williams MR. Covariance mapping in the analysis of ignitable liquids by gas chromatography mass spectrometry. Anal Chem 2006;78(5):1713–8.
18. Carter ME. Essential fiber chemistry. In: Rubenfeld N, editor. Textile research institute. New Jersey: M. Dekker, 1971;1–53.
19. Bendak A, El-Marsafi SM. Effects of chemical modifications on polyester fibers. Medical Journal of IAS 1991;4(4):275–84.

20. Archer NE, Charles Y, Elliot JA, Jickells S. Changes in the lipid composition of latent fingerprint residue with time after deposition on a surface. Forensic Sci Int 2005;154(2):224–39.
21. Zhang Z, Cai J, Ruan G, Li G. The study of fingerprint characteristics of the emanations from human skin arm using the original sampling method by SPME–GC/MS. J Chromatogr B Analyt Technol Biomed Life Sci 2005;822(1–2):244–52.
22. Schoon GAA. The effect of the ageing of crime scene objects on the results of scent identification line-ups using trained dogs. Forensic Sci Int 2005;147(1):43–7.

Additional information and reprint requests:
Kenneth G. Furton, Ph.D.
Department of Chemistry and Biochemistry
International Forensic Research Institute
Florida International University
Miami, FL 33199
E-mail: furtonk@fiu.edu