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I. INTRODUCTION

Casey Anthony (Anthony) was prosecuted for the murder of her daughter, Caylee Anthony and was ultimately found not guilty of murder—or the lesser included offense of manslaughter—but she was convicted for lying to authorities.[1] Caylee was reported missing by Anthony's mother on July 15, 2008.[2] Anthony's Pontiac Sunfire was also reported missing but was later found at a local wrecking yard.[3] Anthony's mother told authorities that the vehicle smelled of rotting flesh[4] and later, a cadaver dog alerted to the rear of the car.[5] Anthony was arrested and charged with murdering her two-year-old

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1. *Casey Anthony Trial Fast Facts*, CNN, http://www.cnn.com/2013/11/04/us/casey-anthony-trial-fast-facts/ (last updated June 29, 2016).

2. *Id.*

3. CNN Wire Staff, *Source: Casey Anthony's Car Destroyed in Florida Junkyard,* CNN (Apr. 22, 2011), http://www.cnn.com/2011/CRIME/08/19/florida.casey.anthony/.

4. Ashleigh Banfield & Jessica Hopper, *Casey Anthony Trial: Car Trunk Had Maggots and Smell of Death*, ABC NEWS (May 27, 2011), http://abcnews.go.com/US/casey-anthony-car-trunk-maggots-smell-death/story?id=13702807.

5. Ashley Hayes, *Deputy: Cadaver Dog Alerted to Casey Anthony's Car, Parents Back Yard*, CNN (June 8, 2011), http://www.cnn.com/2011/CRIME/06/07/florida.casey.anthony.trial/.

daughter.[6] The body of the child was later found in a wooded area near Anthony's parents' house.[7]

This article will discuss a single component of the evidence introduced by the prosecution at trial, the chemical analysis of the volatile organic compounds found in the headspace of a carpet sample taken from the trunk of the Pontiac Sunfire. We will examine the procedures performed on the sample at the Oak Ridge National Laboratory and the chemists' conclusions. Then we will review the arguments presented by the defense as to the reliability of the evidence produced by the Oak Ridge scientists and analyze the judge's denial of the motion to exclude that evidence. Further, we will discuss how, after the trial, the debates between the lawyers and scientists on each side began to concern lawyers and forensic scientists generally. Then we will review more recent progress in the effort to define a human decomposition odor profile. Subsequently, we will analyze the trial court's ruling concerning the Oak Ridge evidence from the perspective of the leading cases regarding the admissibility of scientific evidence. Lastly, we will provide our opinions regarding how the developing science of human-decomposition chemistry will be relevant in future investigations and trials.

II. PRETRIAL MOTIONS AND TRIAL OF CASEY ANTHONY

Anthony's murder trial involved expert testimony about compounds contained in a carpet sample from the trunk of the Pontiac Sunfire where her child's body may have been placed.[8] Dr. Arpad Vass, the prosecutor's expert, concluded that volatile organic compounds (VOCs) and other chemicals contained in the carpet were the result of a human decomposition event,[9] i.e. that Caylee's body was in the trunk long enough to produce chemicals characteristic of human decomposition.[10] Vass had to defend his position in both a pre-trial hearing on the admissibility of his analysis and during trial.[11] Two defense experts, Dr. Kenneth Furton and Dr. Barry Logan, challenged Vass's

6. *Casey Anthony Trial Fast Facts*, *supra* note 1.

7. *Id.*

8. Hayes, *supra* note 5.

9. *Id.*

10. *See id.*

11. *See* John J. Ensminger & Megan A. Ferguson, *The Practical and Legal Significance of the Chemical Analysis of Odor in Relation to Canine Forensic and Judicial Evidence*, *in* CANINE OLFACTION SCIENCE AND LAW: ADVANCES IN FORENSIC SCIENCE, MEDICINE, CONSERVATION, AND ENVIRONMENTAL REMEDIATION 103 (Tadeusz Jezierski, John Ensminger, & L.E. Papet eds., 2016).

conclusions.[12] The trial court denied the motion to exclude Vass's testimony. This article dissects the legal reasoning used to deny the defense's motion to exclude Vass's testimony. Specifically, this article will address the court's analysis of the proffered scientific evidence under the *Frye v. United States* standard.[13] Although the trial judge admitted the evidence under *Frye*, this article argues the judge misapplied *Frye* and that the evidence should have been excluded. This article also considers the evidence against the standard established by the U.S. Supreme Court in *Daubert v. Merrell Dow Pharmaceuticals*.[14] Further, this article argues the *Daubert* framework, which now applies in Florida and many other jurisdictions, would also exclude the evidence. Nevertheless, progress in research on human decomposition events means that such evidence will likely satisfy evidentiary standards in the future.

Jason Forgey, a cadaver dog handler, testified that his dog indicated the presence of human remains on the passenger and trunk areas of the vehicle where Caylee's body was suspected of being placed, as well as one spot in the backyard of the Anthony house.[15] The dog did not alert investigators to the backyard location after technicians had worked the area.[16] Vass testified that upon opening the can in which the carpet had been sent to him in, the cadaver smell or *odor mortis*,[17] was overwhelming.[18] Although the cadaver dog's alerts and the smell of the carpet sample were mentioned in the judge's order denying the motion to exclude Vass's testimony, they were not specifically referred to as reasons for allowing Vass's testimony to be introduced.[19]

12. Mike Schneider, *Novel Forensic Tool Used in Anthony Trial*, STANDARD J. (June 8, 2011 12:00 AM), http://www.standard-journal.com/news/article_a75e4959-54a9-5f15-a823-b814284ffd60.html.

13. *See generally* Frye v. U.S., 293 F. 1013 (D.C. Cir. 1923).

14. *See generally* 509 U.S. 579 (1993).

15. Direct Examination of Forgey at Trial at 01:25, State v. Anthony, No. 2008-CF-15606 (Fla. Cir. Ct. 2011) (video on file in editorial offices of *SMU Science and Technology Law Review*). *See* Ensminger & Ferguson, *supra* note 11 (discussing the correlation of evidence produced by cadaver and narcotics detection dogs with evidence produced by chemical analysis, particularly the analysis of volatile organic compounds).

16. Cross-examination of Forgey at *Frye* Hearing at 04:50, State v. Anthony, No. 2008-CF-15606 (Fla. Cir. Ct. 2011) (video on file in editorial offices of *SMU Science and Technology Law Review*).

17. Arpad A. Vass, *Odor Mortis*, 222 FORENSIC SCI. INT'L 234, 234–41 (2012).

18. Direct Examination of Vass at Trial at 52:30, State v. Anthony, No. 2008-CF-15606 (Fla. Cir. Ct. 2011) (video on file in editorial offices of *SMU Science and Technology Law Review*).

19. *See* State v. Anthony, No. 2008-CF-15606 (Fla. Cir. Ct. Apr. 27, 2011) (order denying motion to exclude unreliable evidence pursuant to *Frye* or in the alternative, motion in limine to exclude (chloroform)).

Therefore, these facts will not be considered in this article as factors that weigh in either a *Frye* or *Daubert* determination of admissibility of chemical evidence.[20]

A. Chemical Analysis of the Trunk Sample

Vass and several colleagues at the Oak Ridge National Laboratory analyzed air from the metal can that contained the carpet sample from Anthony's vehicle.[21] Vass found that "[o]nly a few compounds were observed in this sample (primarily chloroform), so it was deemed necessary to concentrate the sample in order [to] improve the signal-to-noise [ratio] and to increase the sensitivity for lower abundance compounds (if present)."[22] The carpet sample was removed from the metal can and placed in a TedlarR bag for two days, then concentrated by cryogenic trapping (also called "cryotrapping").[23] Ten

20. In *State v. Bailey*, 2016 WL 635154, *1–2 (S.C. Ct. App. 2016), a cadaver dog alerted to decomposition odor inside a house, and four investigators also testified that a laundry room in the house smelled like a corpse. As to the relationship between the dog's alert and the investigators' testimony, the South Carolina Court of Appeals said:

> Even if the officers' testimony in this regard was not specifically cumulative to the cadaver dog evidence that a dead body itself may have been within the home, their testimony at least corroborated that the scent of a decomposing body was found in the home, and it was similarly incriminating inasmuch as it showed the odor of a decomposing body was on a blanket located in a dryer in the home where Bailey had been staying.

Id. at *2. The distinction between two related pieces of evidence being cumulative or corroborative was not elaborated upon, and at an earlier point in the decision, the court probably contradicted itself when it said the canine evidence and the testimony of the investigators regarding the cadaver smell were "merely cumulative." *Id.* at *1. Courts have generally accepted that if a body is not found, "there is no way to test for human remains in order to corroborate a cadaver dog's response." People v. Hudson, 2016 WL 930936, *1 (Mich. Ct. App. 2016). Of course, such perspectives do not consider either a situation like that in the chemical evidence provided in the Anthony prosecution, or the possibility that humans might also detect decomposition.

21. Arpad Vass, Marc Wise, & Madhavi Martin, Final Forensic Report, Orange County Sheriff's Department case number OCSO#08-069208 (Apr. 28, 2009), at 1, http://i2.cdn.turner.com/cnn/2009/images/12/01/body.farm.pdf [hereinafter Vass Forensic Report] (unpublished forensic report) (prepared for the Orange County Sheriff's Department, Orlando, Florida, which provides results of various tests to determine the possibility of a decomposition event).

22. *Id.* Prior to his direct involvement, Dr. Vass recommended Dr. Michael Sigman, a chemist at the University of Central Florida, to collect and test air samples from the vehicle. At the time, Dr. Sigman could not state unequivocally that the odor was that of human decomposition.

23. *Id.* at 2.

milliliters of air from the TedlarR bag were analyzed by gas chromatography/ mass spectrometry (GC/MS),[24] resulting in the detection of the fifty-one chemicals listed in Table 1 below.

TABLE 1: 51 COMPOUNDS IN TRUNK CARPET SAMPLE VIA CRYOTRAPPING AND GC/MS ANALYSIS; PRIOR SOURCES IDENTIFYING COMPOUND AS RELATED TO DECOMPOSITION

Compounds found in:						
Florida trunk Carpet sample	**Decomp. Odor Database**[25]	**Gasoline Vapors**	**Negative Controls**	**Positive Controls** (Montana child)	**Vass (2008)** 30 most import[26]	**Other Sources**[27]
1-Methyl-ethyl benzene	Yes	Yes	No	No	No	—[28]
1,2-Pentadiene	Yes	Maybe	No	No	No	(1), (11)
1-H Indene dihydro	No	No	No	No	No	(1)[29], (11)
2-Butanone	Yes	No	Yes (pizza)	Yes	No	(1), (2), (6)[30], (7), (9), (11)
2-Chloropropane	No	No	No	No	No	—
2-Methyl furan	Yes	No	No	No	No	(6)
2-Methyl hexane	Yes	Yes	Yes (trash bag)	No	No	(1), (9), (11)

24. *Id.* Laser-induced breakdown spectroscopy (LIBS) was also used, according to Vass's report, "to determine if known inorganic components of decompositional events were elevated over the controls and also to determine if the relative abundance ratios of these elements could be used to determine a rough post-mortem interval." *Id.* at 8. Aside from devoting several paragraphs to a description of this methodology, the only observation concerning the findings derived from its application was that it "is interesting to note that every element known to be associated with a decompositional event (that could be detected by this technique) was elevated over control values." *Id.*

25. Arpad A. Vass, Rob R. Smith, Cyril V. Thompson, Michael N. Burnett, Dennis A. Wolf, Jennifer A. Synstelien, Nishan Dulgerian & Brian A. Eckenrode, *Decompositional Odor Analysis Database*, 49 J. FORENSIC SCI. 760, 769 (2004) [hereinafter Vass (2004)], (The "current version of the database is presently being archived at the Federal Bureau of Investigation (FBI), Counterterrorism and Forensic Research Unit, Quantico, Virginia.").

26. Vass Forensic Report, *supra* note 21, at 20.

27. Numbers in brackets in this column indicate position on list in Arpad A. Vass, R.R. Smith, C.V. Thompson, M.N. Burnett, N. Dulgerian & B.A. Eckenrode, *Odor Analysis of Decomposing Buried Human Body,* 53 J. FORENSIC SCI. 384, 384–91 (2008) [hereinafter Vass (2008)].

28. References to chemicals in sources do not mean that the author(s) necessarily identified the chemicals themselves, as some were just summarizing prior findings. Thus, some chemicals listed in more than one paper may have been identified in only one or a smaller number of research projects. The authors cannot claim to have found all references to all chemicals as not all chemical-name discrepancies could be decisively resolved.

29. 1-methyl-2-ethylbenzene identified in (1), (4), and (5).

30. Identified as 1-H-indene, 2,3-dihydro.

2-Methyl propanenitrile	No	No	No	No	No	—[31]
2,3-Butanedione[32]	No	No	No	No	No	(11)[33]
2-Methyl butanal	No	No	Yes (pizza, trip blank)	Yes	No	(6)[34], (14)
3-Methyl butanol	No	Maybe	Yes (pizza)	No	No	(11), (14), (15), (16)
3-Methyl hexane	Yes	Maybe	Yes (trash bag, vehicle interior, garage air)	No	No	(1), (9), (11)
3-Methyl pentane	Yes	Yes	Yes (same as previous)	No	No	(1), (6), (11)
3-Methyl butanal	Yes	No	Yes (Knoxville carpet, pizza)	Yes	No	(2), (6), (7), (9), (11), (14), (15), (17)
4-Methyl-2-pentanone	No	No	No	No	No	—
Acetaldehyde (ethanal)	Yes	Yes	Yes (Knoxville carpet, pizza)	Yes	No	(1), (6), (11), (15), (16)
Acetic acid, methyl ester	Yes	No	No	No	No	(11)[35]
Acetone (2-propanone)	Yes	No	Yes (Knoxville carpet, pizza)	No	No	(1), (2), (4), (6), (9), (11), (15), (16)[36]
Benzene	Yes	Yes	Yes (multiple)	Yes	Yes [9]	(1), (5), (6), (7), (9), (11), (15)
Butanal	Yes	No	Yes (Knoxville carpet, trip blank)	Yes	No	(6)[37], (11)[38], (15), (17)

31. 2-butanone (methyl ethyl ketone – MEK).

32. Norma Iris Caraballo, Identification of Characteristic Volatile Organic Compounds Released During the Decomposition Process of Human Remains and Analogues 194, tbl. 40 (Feb. 28, 2014) (unpublished Ph.D. dissertation, Florida International University), http://digitalcommons.fiu.edu/etd/1391/ (identifying propanenitrile, 3-dimethylamino from pig remains).

33. Vass Forensic Report, *supra* note 21, at 20 (lists 2,3-butanediene, which appears to the authors to be a mistake because a diene cannot have double bonds at adjacent carbons as the name indicates. In contrast, the compound 2,3-butanedione is a known fermentation product.).

34. Identified from pig decomposition.

35. Stating that "it was noted that when animal carcass VOCs are analyzed, 2-methyl butanal is always greater than 3-methyl butanal (this trend is also seen in animal fecal samples). This is reversed (or equal – within 10% in one instance) in human remains and is potentially a key marker to determine if the remains are human or not, especially in older gravesites." (11) lists 2-methylbutanal only for pig remains, though 3-methylbutanal for human and pig remains.

36. Listed as an alternate name for methyl acetate; acetic acid mentioned as trace from laboratory environment in (15).

37. Mentioned as trace from laboratory environment in (15).

38. Noting that "as one approaches the late phase [of decomposition], a noticeable increase in aldehydes becomes apparent with significant increases in

Butanoic acid, methyl ester	Yes	No	No	No	No	(1)[39], (7)
Carbon disulfide	Yes	No	No (but trace on Knoxville carpet)	Yes	Yes [19]	(1), (4), (5), (6), (7), (11), (15), (18)
Carbon tetrachloride (tetrachloromethane)	Yes	No	No (but trace on Knoxville carpet)	Inconclusive	Yes [1]	(4), (5), (11), (14)
Chloroethane	Yes	No	No	No	No	—
Chloroform (trichloromethane)	Yes	No	No (trace on Knoxville carpet)	No	Yes [12]	(4), (5), (6), (7), (9), (11), (15)[40]
Chloromethane	Yes	No	No	Yes	No	—
Decanal	Yes (trace)	No	No	No	Yes[41] [16]	(4), (5), (6), (7), (11), (14), (16), (18)
Dichloroethene	Yes	No	No	Yes	No	(6)[42]
Dichloromethane	Yes	No	No	Yes	No	—[43]
Dimethyl trisulfide	Yes	No	No	Yes	Yes [15]	(1), (2), (4), (5), (6), (7), (9), (11), (15), (18)
Dimethyl undecane	No	No	No	No	No	—[44]
Dimethyl disulfide	Yes	No	No (but trace on vehicle interior)	Yes	Yes [7]	(1), (2), (4), (5), (6), (7), (9), (11), (13), (14), (15), (17)
Ethanol	Yes	Yes	Yes (Knoxville carpet, pizza)	Yes	No	(1), (2), (6), (11), (16), (16)
Etheneamine	No	No	No	No	No	—
Ethyl benzene	Yes	Yes	No	No	Yes [13]	(4), (6), (7), (9), (11)[45]
Hexane	Yes (trace)	Yes	Yes (Knoxville carpet, vehicle interior, pizza)	No	Yes [20]	(1), (2), (4), (6), (7), (9), (11), (18)[46]
Hexanol	Yes	No	No	No	No	(1), (4), (7), (9), (13)[47]

compounds such as butanal, decanal, heptanal, nonanal and octanal (among others)." Vass, *Odor Mortis*, *supra* note 17, at 239.

39. (11) lists only as to pig remains.

40. Finding butanoic acid 2-methyl ester.

41. Mentioned as trace from laboratory environment by researchers in (15).

42. Not considered in Vass Forensic Report, *supra* note 21, due to trace level.

43. 1,2-dichloro-ethene.

44. Mentioned as solvent in (7), (11); mentioned as trace from laboratory environment in (15), (19).

45. (11) at tbls. 38, 39 refers to 2,6-dimethylundecane and 2,5-dimethylundecane in pig remains.

46. Also named phenylethane.

47. Mentioned as trace from laboratory environment in (15); hexane and decanal were listed as trace in Vass Forensic Report, *supra* note 21, at tbl. 1.

Isobutanal	Yes	No	Yes (pizza)	No	No	(11)[48]
Isooctane	Yes	Yes	No	No	No	(1), (2), (6), (11), (18)[49]
Limonene/ Pinene	Yes	No	Yes (trash)	No	No	(1)[50], (2)[51], (9)[52], (11)
Methanethiol	Yes	No	No	Yes	No	(15), (16), (18)[53]
Methanol	Yes	Yes	Yes (Knoxville carpet, pizza)	No	No	(1), (17), (18)[54]
Naphthalene	Yes	Yes	Yes (trash bag)	No	Yes [5]	(2), (4), (5), (6), (7), (9), (11), (15)
Octane	Yes	Yes	Yes (vehicle interior, garage air, trip blank)	No	No	(1), (2), (6), (11), (14), (16), (18)
Pentane	Yes	No	Yes (vehicle interior, pizza, garage air, trip blank)	No	No	(6), (9), (14)
Tetrachloroethene	Yes	No	Yes (trash bag, garage air; found in degreasers)	No	Yes [4]	(2), (4), (5), (6), (11), (13)
Tetrahydro furan	No	No	No	No	No	—[28]
Toluene	Yes	Yes	Yes (Knoxville carpet, vehicle interior, pizza)	Yes	Yes [2]	(1), (2), (4), (5), (6), (7), (11), (13)
Trichloroethene	Yes (trace)	No	No (garage air)	No	Yes[16] [22]	(4), (7), (9), (11)
Trimethyl pentene	Yes	Maybe	No	No	No	—
Xylene(s)	Yes	Yes	Yes (trash bag, vehicle interior, pizza)	No	No	(1), (2), (6), (13)
51	**41** (Yes)	**24** (in bold)	**16** (in bold)	*13*[55]	5[56]	N/A

Legend for references in final three columns on right: (1) Milt Statheropoulos, Chara Spiliopoulou, Agapios Agapiou, *A Study of Volatile Organic Compounds Evolved From Decaying Human Body*, 153 FORENSIC SCI. INT'L. 147, 147–155 (2005); (2) M. Statheropoulos, A. Agapiou, C. Spiliopoulos, G.C. Pallis & E. Sianos, *Environmental Aspects of VOCs Evolved in Early Stages of Human Decomposition*, 385 Sci. of the Total Env't 221, 221–27 (2007); (3) Arpad A. Vass, *Beyond the Grave – Understanding Human Decomposition*, 28 MICROBIOLOGY TODAY 190 (2001); (4) Arpad A. Vass, Rob R. Smith, Cyril V. Thompson, Michael N. Burnett, Dennis A. Wolf, Jennifer A. Synstelien, Nishan Dulgerian & Brian A. Eckenrode, *Decompositional Odor Analysis Database*, 49 J. OF FORENSIC SCI., 760, 769 (2004); (5) Arpad A.

48. 1-hexanol in most references; mentioned as laboratory trace in (15).

49. (11) lists as alternative name for 2-methylpropanal; listed by (6) and (7) under this name. Vass testified that isobutyric acid, which can be created by oxidization of isobutanal, was detected in the carpet sample. Direct Examination of Vass at Trial at 51:20, *supra* note 18.

50. All listed as octane.

51. di-limonene, alpha-pinene.

52. di-limonene.

53. d-limonene.

54. (11) lists for pig decomposition.

55. *See* K. Tomita, *On Putrefactions and Floatations of Dead Bodies under Water*, 24 HIROSHIMA J. MED. SCI. 117, 117–52 (1975).

56. Positive controls were not used to eliminate (or confirm) compounds under consideration.

Vass, R.R. Smith, C.V. Thompson, M.N. Burnett, N. Dulgerian & B.A. Eckenrode, *Odor Analysis of Decomposing Buried Human Body*, 53 J. Forensic Sci. 384 (2008); (6) Arpad A. Vass, *Odor Mortis*, 222 Forensic Sci. Int'l. 234, 234–41 (2012).; (7) Lauryn E. DeGreeff, *Development of a Dynamic Headspace Concentration Technique for the Non-Contact Sample of Human Odor Samples and the Creation of Canine Training Aids* 94, tbl. 12 (2010) (unpublished Ph.D. dissertation, Florida Int'l Univ., Dept. of Chemistry and Biochemistry), http://digitalcommons.fiu.edu/cgi/viewcontent.cgi?article=1382&context=etd.; (8) Lauryn E. DeGreeff, Allison M. Curran, Kenneth G. Furton, *Evaluation of Selected Sorbent Materials for the Collection of Volatile Organic Compounds Related to Human Scent Using Non-Contact Sampling Mode*, 209 FORENSIC SCI. INT'L. 133, 133–142 (2011); (9) Lauryn E. DeGreeff & Kenneth G. Furton, *Collection and Identification of Human Remains Volatiles by Non-Contact, Dynamic Airflow Sampling and SPME-GC/MS Using Various Sorbent Materials*, 401(4) Analytical and Bioanalytical Chemistry 1295, 1295–1307 (2011); (10) L. DeGreeff, B. Weakley-Jones, KG Furton, *Creation of Training Aids for Human Remains Detection Canines Utilizing a Non-Contact, Dynamic Airflow Volatile Concentration Technique*, 217 FORENSIC SCI. INT'L. 32, 32–38 (2012); (11) Norma Iris Caraballo, Identification of Characteristic Volatile Organic Compounds Released During the Decomposition Process of Human Remains and Analogues (Feb. 28, 2014) (unpublished Ph.D. dissertation, Florida International University) http://digitalcommons.fiu.edu/etd/1391/.; (12) RESI GERRISTEN & RUDD HAAK, K9 FRAUD!: FRAUDULENT HANDLING OF POLICE SEARCH DOGS (2010); (13) Erin M. Hoffman, Allison M. Curran, Nishan Dulgerian, Rex A. Stockham, Brian A. Eckenrode, *Characterization of the volatile Organic Compounds Present in the Headspace of Decomposing Human Remains*, 186 FORENSIC SCI. INT'L. 6, 6–13 (2009); (14) E. Rosier, S. Loix, W. Develter, W. Van de Voorde, J. Tytgat & E. Cuypers, *The Search for a Volatile Human Specific Marker in the Decomposition Process*, 10(9) PLOS/One e0137341, 1–15 (2015); (15) Sebastien Paczkowski & Stefan Schütz, *Post-Mortem Volatiles of Vertebrate Tissue*, 91(4) Applied Microbiology and Biotechnology 917, 917–35 (2011); (16) Agapios Agapiou, K. Mikedi, Chara Spiliopolou, Milt Statheropoulos, *Analysis of Volatile Organic Compounds Released From the Decay of Surrogate Human Models Simulating Victims of Collapsed Buildings by Thermal Desorption – Comprehensive Two-Dimensional Gas Chromatography – Time of Flight Mass Spectrometry*, 883 ANALYTICA CHIMICA ACTA 99, 99–108 (2015); (17) Sonja Stadler, Pierre-Hugues Stefanuto, Michal Brokl, Shari L. Forbes & Jean-Francois Focant, *Characterization of Volatile Organic Compounds from Human Analogue Decomposition Using Thermal Desorption Coupled to Comprehensive Two-Dimensional Gas Chromatography—Time-of-Flight Mass Spectrometry*, 85(2) Analytical Chemistry 998 (2013); (18) E. Rosier, E. Cuypers, M. Dekens, R. Verplaestse, W. Develter, W. Van de Voorde, D. Maes, J. Tytgat, *Development and Validation of a new TD-GC/MS Method and its applicability in the Search for Human and Animal Decomposition Products*, 406 ANALYSIT BIOANALYSIT CHEM 3611, 3611–3619 (2014).

Of the fifty-one chemicals found in the air sample by the GC/MS analysis, Vass and his colleagues considered forty-one to be consistent with decomposition events because they were listed in the Decompositional Odor Database, which contains 478 chemicals associated with human decomposition.[57] The Federal Bureau of Investigation (FBI), Office for Victim Assistance, sponsored Oak Ridge National Laboratory's creation of the Decompositional Odor Database.[58] However during the pre-trial motion to exclude the chemical evidence, the agency declined to authorize release of the database to the defense's expert witnesses.[59] The correlation of the compounds identified through GC/MS analysis with the database thus came

57. After two were eliminated as trace.

58. The Decompositional Odor Database was developed by Oak Ridge National Laboratory pursuant to a contract with the Department of Energy, contract number DE-ACO5-000R22725. *See Oak Ridge National Laboratory, Contract with the Department of Energy*, DEP'T OF ENERGY, ORNL SITE OFFICE (Apr. 1, 2015), http://web.ornl.gov/adm/prime_contract/Entire_Contract.pdf.

59. It must be questioned whether there is any continued justification for the FBI keeping the database proprietary to itself and those who developed it. Published papers have made many of the compounds in the database public. *See* Caraballo, *supra* note 31, at 189–94 (listing at least 173 chemicals associated specifically with human decomposition from prior studies and adds eleven more from original research); E. Rosier, S. Loix, W. Develter, W. Van de Voorde, J. Tytgat & E. Cuypers, *The Search for a Volatile Human Specific Marker in the Decomposition Process*, 10(9) PLOS/ONE e0137341, 5 (2015) [hereinafter Rosier (2015)] (listing 452 compounds). Thus, a significant portion of the database is likely now public.

solely from the report of experts at the Oak Ridge National Laboratory and Vass's testimony. A significant number of the compounds identified as part of the database were not previously identified in peer-reviewed literature regarding human decomposition events. Nevertheless, subsequently published research has identified some of those compounds.[60] It should also be noted that at least two of the fifty-one chemicals first identified from the sample that were listed by Vass as not in the database have since been identified in scientific literature as associated with human decomposition.[61]

The Oak Ridge analysis also eliminated seventeen of the chemicals "known or possible gasoline constituents" because of the likelihood that gasoline or gasoline vapor could have been present in the trunk of the Pontiac.[62] Control samples tested to eliminate compounds that could be explained as coming from other sources in the trunk included: (1) carpet samples from a vehicle found in a junkyard that was unrelated to the case; (2) pizza (because trash found in the Pontiac included pizza remains); (3) laboratory air where the sample was stored (to see if contaminants in the air could explain any of the fifty-one chemicals found in the analysis); and (4) samples from a road-kill squirrel allowed to decompose on a control carpet sample (because a non-human animal might have decomposed in the trunk).[63] Testing was also conducted on the trash bags found in the Pontiac, the vehicle air, and the air of the garage where the vehicle was stored.[64] A positive control sample was also analyzed. The positive control sample came from a section of blanket where a three-year-old child had decomposed for approximately three months in Montana.[65] The presence of identical compounds in the positive control sample and the trunk sample would suggest that a decomposition event occurred in the Pontiac's trunk. Of the twenty-four compounds that did not overlap with gasoline constituents,[66]

60. A considerable amount of the cross-examination of Vass sought to emphasize differences between the published research of Vass and his colleagues and those of Statheropoulos and his colleagues.

61. *See* M. Statheropoulos, C. Spiliopoulou & A. Agapiou, *A Study of Volatile Organic Compounds Evolved from the Decaying Human Body*, 153 FORENSIC SCI. INT'L 147, 151 (2005) [hereinafter Statheropoulos (2005)]) (1-H indene dihydro). *See also* Vass, *Odor Mortis*, *supra* note 17, at 237 (2-methyl butanal). *See also supra* Table 1, right column.

62. Vass Forensic Report, *supra* note 21, at 3.

63. *Id.* at 2.

64. *Id.* at 4.

65. *Id.*

66. The twenty-four compounds were 2-butanone; *2-methyl furan*; 3-methyl butanal; *acetic acid, methyl ester*; acetone (2-propanone); butanal; *butanoic acid, methyl ester*; *carbon disulfide*; *carbon tetrachloride (tetrachloromethane)*; *chloroethane*; *chloroform (trichloromethane)*; *chloromethane*; *decanal*; *dichloroethene*; *dichloromethane*; *dimethyl trisulfide*;

sixteen remained "whose source could not be potentially linked to any of the controls which were analyzed."[67]

Of the sixteen chemicals that did not overlap with either gasoline or the controls,[68] "seven were identified as significant human decomposition chemicals."[69] The Oak Ridge forensic analysis chose to consider only those chemicals listed in Vass (2008), which identified thirty "key markers of human decomposition which were detectable at the soil surface" when a body is buried below.[70] But these key markers apply to buried human remains which, as discussed below, can create different chemical profiles than found with human bodies decomposing above the surface, as in the case here. Nevertheless, Vass (2008) states that of the thirty key markers, "19 were also detected when collecting TST [triple sorbent trap] air samples above corpses decaying on the surface (unburied), confirming the hypothesis that they are originating from the corpse."[71]

The thirty key markers were chosen not solely because of the amounts of these chemicals that might be measured, but also because a "decision tree" analysis suggested they were highly informative markers. The decision tree analysis was described in Vass (2008) as follows:

1. Reproducibility of detection (between burials and regardless of depth).
2. Detection of the compound as a component of human bone odor.
3. Abundance of the compound.
4. Longevity of detection.
5. Background control concentrations.

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dimethyl disulfide; *hexanol*; isobutanal; limonene/pinene; *methanethiol*; pentane; tetrachloroethene; and *trichoroethene*. The sixteen compounds in italics were not eliminated due to their presence in other negative controls in the subsequent elimination step performed by Vass and his colleagues. Carbon disulfide, carbon tetrachloride (tetrachloromethane), chloroform (trichloromethane), decanal, dimethyl trisulfide, dimethyl disulfide, and trichoroethene are contained in the list of thirty in Vass (2008), *supra* note 26, at 384, 388. Decanal and trichoroethene were eliminated from the final analysis as only appearing in the carpet sample at a trace level. *See* Vass Forensic Report, *supra* note 21, at 5.

67. Vass Forensic Report, *supra* note 21, at 5.

68. For reference, these sixteen chemicals did not overlap with gasoline or controls: 2-methyl furan, acetic acid methyl ester, butanoic acid methyl ester, carbon disulfide, carbontetrachloride, chloroethane, chloroform, chloromethane, decanal, dichloroethene, dichloromethane, dimethyl trisulfide, dimethyl disulfide, hexanol, methanethiol and trichloroethene. *See id.*

69. *Id.*

70. Vass (2008), *supra* note 26, at 387.

71. *Id.*

6. Whether the compounds were detected in surface decomposition events.
7. Whether the compounds were detected in relevant areas other than the University of Tennessee's decay research facility (e.g., Noble, GA; morgues, forensic cases submitted to our laboratory, reports from other researchers).
8. Uniqueness of the compound.
9. Chemical class trends.
10. Effects of the environment (temperature, moisture, barometric pressure).[72]

Thus, the decision tree incorporated quantitative and qualitative assessments.[73] However, Vass and his team did not provide threshold amounts of these thirty chemicals that would be sufficient to find the occurrence of a human decomposition event. Vass and his team state that with their techniques for sampling the compound concentrations at the surface above a grave (using a "capture hood"), there were sometimes "elevated, transient concentration spikes for unknown reasons . . . ."[74] They do not specify when such elevations might occur simultaneously in several chemicals. They also acknowledge that "many of the 30 compounds . . . are not very unique and can in fact be found in many outdoor samples taken virtually anywhere."[75]

Vass further stated that the "next logical progression in this study will be to develop and modify analytical instrumentation which can detect a significant proportion of these thirty compounds in the specified range of concentrations and chemical groupings."[76] Such a technique might provide a basis for arguing that the five remaining chemicals appear in "specified ranges" consistent with a human decomposition event that occurred in the trunk of the car.[77] However, the chemicals were not quantified in preparation for trial.

Although the use of a proprietary database to filter the initial fifty-one chemicals to forty-one was certainly something the defense could, and did, object to, it must be noted that the initial step of comparing the fifty-one

72. *Id.* at 390.

73. *See id.*

74. *Id.*; *see also* P. Armstrong, K.D. Nizio, K.A. Perrault & S.L. Forbes, *Establishing the Volatile Profile of Pig Carcasses as Analogues for Human Decomposition during the Early Postmortem Period*, 2(2) HELIYON e00070, 13 (2016) (studying decomposition of pig carcasses as analogues for human decomposition noting the "VOC profile of the early postmortem period is highly dynamic, with the average VOC abundance of different compound classes shifting considerably between sampling days . . . .").

75. Vass (2008), *supra* note 26, at 387.

76. *Id.* at 390.

77. *See* Vass Forensic Report, *supra* note 21, at 8–9.

chemicals identified in the trunk sample to the Decompositional Odor Database did nothing to change the final outcome. The comparison with the top thirty chemicals would have eliminated the ten compounds eliminated in the initial paring down to forty-one.[78] As indicated in Table 2, many of the thirty chemicals listed in Vass (2008) were not found in the trunk sample, nor were many published elsewhere in connection with human decomposition events.[79] Also, while the Vass (2008) noted that nineteen of the thirty key markers were identified in surface decomposition cases, it is possible that a different set of key markers should be selected for surface decomposition events.[80]

78. Although not stated in any of the case documents that the authors have been able to analyze, it is possible that the introduction of the filtering step of comparing the chemicals to the list of thirty in Vass (2008), *supra* note 26, could have been introduced into the forensic analysis to overcome objections by the defense to the refusal of the FBI or the inability of the prosecution to produce the list of 478 compounds in the proprietary database. Had the confidentiality of the database become an issue for Judge Perry in ruling on the motion to exclude Vass's testimony, a strategy that established that this step was superfluous to the final list of compounds from which a human decomposition event was being argued might have been seen as a way to overcome the judge's qualms.

79. Caraballo, *supra* note 31, at 92 tbl. 9 (listing thirty-one "compounds selected to be used for method optimization,"). Only six of Caraballo's compounds are in Vass's table of the thirty most important chemicals for human decomposition. *See* Vass (2008), *supra* note 26, at 387.

80. Vass said in testimony that Statheropoulos had identified nineteen of his thirty chemicals. Cross-examination of Vass at *Frye* Hearing at 03:50, State v. Anthony, No. 2008-CF-15606 (Fla. Cir. Ct. 2011) (video on file in editorial offices of *SMU Science and Technology Law Review*). In M. Statheropoulos, A. Agapiou, C. Spiliopoulos, G.C. Pallis & E. Sianos, *Environmental Aspects of VOCs Evolved in Early Stages of Human Decomposition*, 385 SCI. OF THE TOTAL ENV'T 221, 224 (2007) [hereinafter Statheropoulos (2007)], tbl. 1, *infra*, compares results from that paper with those of Statheropoulos (2005), *supra* note 61 and Vass (2004), *supra* note 57, and lists fifteen chemicals (out of thirty-one) that both teams had found. This ratio has probably changed towards increasing overlap with Vass's 2012 paper. Comparing Statheropoulos and Vass to other researchers, who did not work on decomposition of whole bodies, DeGreeff shows that of eighty-seven compounds identified with decomposition by various researchers, twenty-five were not identified by either Vass or Statheropoulos. *See* Lauryn E. DeGreeff, Development of a Dynamic Headspace Concentration Technique for the Non-Contact Sample of Human Odor Samples and the Creation of Canine Training Aids, 94, tbl. 12 (2010) (unpublished Ph.D. dissertation, Florida Int'l Univ., Dept. of Chemistry and Biochemistry), http://digitalcommons.fiu.edu/cgi/viewcontent.cgi?article=1382&context=etd. The number of compounds identified with decomposition has increased, but would undoubtedly be greater still if the Oak Ridge database were made public. *See* Lauryn E. DeGreeff & Kenneth G. Furton, *Collection*

By limiting the evidence to those compounds on the list of thirty from Vass (2008), Vass's expert report reduced the number of chemicals under consideration to the following seven chemicals: carbon tetrachloride, dimethyl disulfide, chloroform, dimethyl trisulfide, carbon disulfide, decanal, and trichloroethene. The latter two were eliminated because they were only found in trace amounts, which left five compounds consistent with a human decomposition event.[81] Vass indicated that chloroform and trichloroethene were "[n]ot detected during surface decomposition."[82] Vass's report eliminated trichloroethene based on its trace level.[83] In his expert witness report, he acknowledges that chloroform is "primarily detected in deprived oxygen (anaerobic) decompositions," so arguably it should also have been eliminated from consideration.[84]

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and Identification of Human Remains Volatiles by Non-Contact, Dynamic Airflow Sampling and SPME-GC/MS Using Various Sorbent Materials, 401(4) ANALYTICAL & BIOANALYTICAL CHEM. 1295, 1296, tbl. 1 (2011) [hereinafter DeGreeff & Furton (2011)] (listing 111 separate compounds associated with human decomposition); Rosier (2015), *supra* note 59, at 5 (identifying the largest number of decomposition chemicals (452) found in any peer-reviewed publication, although this included decomposition data for a number of different species of animals). Unfortunately, this team did not provide a comprehensive list of human decomposition compounds.

81. Vass Forensic Report, *supra* note 21, at 5.

82. Vass (2008), *supra* note 26, at 387.

83. Vass Forensic Report, *supra* note 21, at 5.

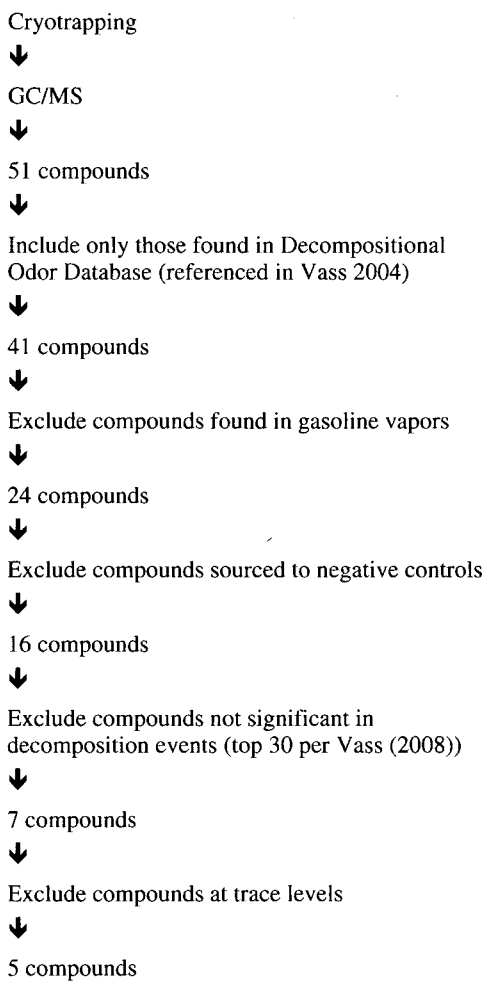
84. *Id.*; *see* Shari L. Forbes & Katelynn A. Perrault, *Decomposition Odour Profiling in the Air and Soil Surrounding Vertebrate Carrion*, 9(4) PLOS/ONE e95107, 1 (2014) (concluding that "soil and air samples produce distinct subsets of VOCs that contribute to the overall decomposition odor."). They note:

> Overall, there were fewer compounds detected in the air samples above the remains compared to the soil samples below the remains. This may have resulted from the rapid dispersion of VOCs in air due to wind, evaporation, or other environmental factors. It could have also resulted from the physical, chemical and microbiological properties of the soil.

Id. at 7. Thus, some of the VOCs detected in soil may have come from bacteria and fungi on and near decomposing remains. Katelynn A. Perrault, Pierre-Hugues Stefanuto, Barbara H. Stuart, Tapan Ral, Jean-Francois Focant & Shari L. Forbes, *Reducing Variation in Decomposition Odour Profiling Using Comprehensive Two-Dimensional Gas Chromatography*, 38(1) J. SEPARATION SCI. 73, 77 (2015) (describing the need to establish VOC profiles of soils and noting that there is considerable variation in that profile across soils). *See* Sebastien Paczkowski & Stefan Schütz, *Post-Mortem Volatiles of Vertebrate Tissue*, 91(4) APPLIED MICROBIOLOGY & BIOTECHNOLOGY 917, 918–19 (2011) (noting that many microbes are already present inside and on a corpse at the time of death, but others can come from the environment during decomposition, and

In sum, the steps by which Vass's expert report reduced fifty-one chemicals from the initial analysis of the trunk sample to five, which he associated with a human decomposition event, involved the series of steps graphically depicted in Figure 1.

FIGURE 1. OAK RIDGE PROCEDURE FLOWCHART



will vary depending on the environment). *See also* Jessica L. Metcalf, Zhenjiang Zech Xu, Sophie Weiss, Simon Lax, Will Van Treuren, Embriette R. Hyde, Se Jin Song, Amnon Amir, Peter Larsen, Naseer Sangwan, Daniel Haarmann, Greg C. Humphrey, Gail Ackermann, Luke R. Thompson, Christian Lauber, Alexander Bibat, Catherine Nicholas, Matthew J. Gebert, Joseph F. Petrosino, Sasha C. Reed, Jack A. Gilbert, Aaron M. Lynne, Sibyl R. Bucheli, David O. Carter & Rob Knight, *Microbial Community Assembly and Metabolic Function During Mammalian Corpse Decomposition*, 351 SCI. 158 (2016).

By reducing the number of chemicals under consideration for establishing a human decomposition event to thirty, seven of which were detected in the carpet sample, Vass effectively increased the percentage of chemicals used in the human decomposition argument. That is, seven out of thirty is twenty-three percent, while sixteen out of 478 is three percent.[85] Also, the denominator in the second fraction was unavailable for any analysis by other experts or even the court, so using the fraction 7/30 created a step in Vass's argument that should have been open to analysis and criticism by other forensic experts. Arguably, the litigation itself influenced choices made in the scientific argument of Vass, and could or should have been designed to satisfy the "peer review" approach to reliability.[86]

At trial, the defense tried to reduce the number of chemicals further using the testimony of Furton, part of whose direct examination was as follows:

> Baez (lead defense counsel): Do you have an opinion after looking at the five chemical compounds that Dr. Vass found in this case as to whether those compounds are the make-up of human decomposition?
>
> Furton (expert witness): Yes, I do.
>
> Baez: And can you share with the ladies and gentlemen of the jury what those opinions are?
>
> Furton: It's my opinion that those five compounds are not unique to human decomposition because two of the compounds, chloroform and carbon tetrachloride, are found in household products such as bleach and the three methyl sulfides . . . have been reported in decomposing organic matter. It doesn't even have to be another animal. They've been reported in urban waste, trash bins for example . . . .[87]

During his cross-examination of Vass, Jose Baez also suggested the five chemicals Vass offered as evidence of human decomposition should be reduced to three. To make this argument, Baez relied on the possibility that chloroform and carbon tetrachloride could have been added by other items in the trunk, such as trash. The prosecutor, Jeffrey Ashton, attacked Furton for

85. If two additional chemicals in the initial list of fifty-one can actually be associated with decomposition, this fraction would have to be altered by increasing the denominator.

86. *See* William L. Anderson, Barry M. Parsons, & Drummond Rennie, Daubert's *Backwash: Litigation-Generated Science*, 34 U. MICH. J.L. REF. 619, 619–82 (2001) (describing the risks of litigation-generated science).

87. Direct Examination of Furton at Trial at 2:02:20, State v. Anthony, No. 2008-CF-15606 (Fla. Cir. Ct. 2011) (video on file in editorial offices of *SMU Science and Technology Law Review*).

suggesting that the amount of chloroform found in the trunk could have been from trash:

> Ashton: Is there an FDA limit on how much chloroform can be in a food product?
> Furton: Yes.
> Ashton: What's that limit?
> Furton: I don't recall the limit off the top of my head.
> Ashton: Is it in the parts per billion range?
> Furton: Yes, it's in the low level.[88]

Instead, Vass buttressed his argument with strong insistence that any other explanation for the presence of the five chemicals was, at a best, a "remote possibility."[89] Vass claimed that such "an unusual variety of products or materials (not present in the trunk at the time of vehicle discovery) may have had some contribution to the overall chemical signature," but was not a viable explanation.[90] In contrast, Furton's expert report argued:

> The five chemicals used to draw conclusions about the possibility of a decompositional event are known to be present in cleaning products including bleach (chloroform and carbon tetrachloride) and in non-human decompositional events, including composting (carbon disulfide, dimethyl disulfide, dimethyl trisulfide). It is therefore critical to compare the concentrations/relative ratios of chemicals detected and compare these to databases of background materials and non-human decompositional events in order to determine if the levels detected are statistically significan[t].[91]

Vass provided virtually no analysis of the positive control sample. He described the positive control in his expert witness report as "a forensic case in Montana where a 3-year-old child (decedent) was wrapped in a blanket and allowed to decompose over a three-month period in the trunk of a car . . . ."[92] In Vass's table of compounds—found in the analysis of the carpet sample—he indicated that only thirteen of the fifty-one compounds found in

88. Cross-examination of Furton at Trial at 2:12:45, State v. Anthony, No. 2008-CF-15606 (Fla. Cir. Ct. 2011) (video on file in editorial offices of *SMU Science and Technology Law Review*). Rosier (2015), *supra* note 59, at 5 (identifying 452 compounds from human and animal remains, refer to chloroform not as a chemical indicative of human decomposition but as a trace from the laboratory environment detectible in a blank jar).

89. Vass Forensic Report, *supra* note 21, at 16.

90. *See id.* at 16.

91. Kenneth G. Furton, Final Forensic Report, in the Case of State v. Anthony, Case No.: 48-2008-CF-15606 (Jan. 16, 2011) at 8 [hereinafter Furton Forensic Report].

92. Vass Forensic Report, *supra* note 21, at 3.

the carpet were present in the positive control blanket sample. Of those thirteen, only five were found in the list of thirty, which include: benzene, *carbon disulfide*, *dimethyl trisulfide*, *dimethyl disulfide*, and toluene. The three chemicals in italics overlap with the five that Vass focused on after his elimination process with the trunk sample.[93] If the positive control results were included in the filtering process, arguably only these three chemicals should have been available to propose a human decomposition event. Just as it was not possible to say what portion of the compounds Vass identified were from a human decomposition event after excluding negative controls, there is no statistical evidence to support an overlap with the positive control sample. Moreover, this positive control sample was hardly an identical control because the environment was very different—Montana as opposed to Florida—and the body was at a later stage of decomposition—three months as opposed to a few weeks.

TABLE 2: 30 MOST IMPORTANT COMPOUNDS FOR HUMAN DECOMPOSITION PER ARPAD A. VASS, R.R. SMITH, C.V. THOMPSON, M.N. BURNETT, N. DULGERIAN & B.A. ECKENRODE (2008).

Rank	Compound[1]	Florida Carpet Sample
1	Carbon tetrachloride	Yes
2	Toluene	yes (but found in gas vapors)
3	Ethane, 1,1,2-trichloro-1,2,2-trifluoro	No
4	Tetrachloroethene	No
5	Naphthalene	yes (but found in gas vapors)
6	Trichloro-monofluoro-methane	No
7	Dimethyl disulfide	Yes
8	1,4 dimethyl benzene (*p*-xylene)	Yes
9	Benzene	yes (but found in gas vapors)
10	Dichlorodifluoro-methane	No
11	1,2 dimethyl benzene (*o*-xylene)	Yes
12	Chloroform	yes (extreme amount)
13	Ethylbenzene	yes (but found in gas vapors)
14	Styrene	No
15	Dimethyl trisulfide	Yes
16	Decanal	(trace)
17	Sulfur dioxide	No
18	Nonanal	No
19	Carbon disulfide	Yes
20	Hexane	yes (but found in gas vapors)
21	Benzenemethanol, α,α-dimethyl	No
22	Trichloroethene	(trace)
23	1-ethyl, 2-methyl benzene	No
24	1-methoxypropyl benzene	No
25	Hexadecanoic acid, methyl ester	No

93. *Id.* at 5.

26	1,2 Benzene-dicarboxylic acid, diethyl ester	No
27	Undecane	No
28	Methenamine	No
29	Dichlorotetrafluoro-ethane	No
30	1,1-dichloro-1-fluoro-ethane	No

[1]Five compounds ultimately considered consistent in Anthony's case with human decomposition are in bold.

B. Report of Primary Defense Expert

Excluding chemicals that could be found in gasoline vapors that could be sourced to controls, or those found only in trace amounts, would not likely give rise to dispute in the scientific community. It would, however, be likely that many scientists would argue the use of a proprietary and confidential database to reduce the number of chemicals from fifty-one to forty-one was improper. In addition, excluding compounds not on a list in only one published paper, does not comport with generally accepted procedures in the scientific community.[94] As stated by Furton in his expert witness report:

> The methods employed by Vass and coworkers at Oak Ridge National Laboratory are still in the experimental stage and do not have sufficient databases of chemicals present in background materials and an insufficient number of decompositional materials and conditions to make [. . .] scientific conclusions with reasonable degrees of scientific certainties using established statistical techniques. The data presented in the reports submitted does not allow for the calculation of error rates or the likelihood of false positive and false negatives under the conditions employed. Only a small fraction of the 478 "specific volatile compounds associated with burial decomposition" and the 30 chemicals Vass et al. [2008] have reported as "key markers of human decomposition" were present in the tested samples with five chemicals used to draw conclusions about the possibility of a decompositional event occurring (chloroform, carbon tetrachloride, carbon disulfide, dimethyl disulfide, dimethyl trisulfide). None of the fluorinated compounds Vass has reported to be specific for human decomposition were detected in the samples tested. Rather than interpreting that the lack of human specific fluorinated compounds as an indicator of a non-human decompositional event, Vass and coworkers speculated that this may indicate that their technique may not

94. *See* Cross-examination of Vass at Trial at 25:00, State v. Anthony, No. 2008-CF-15606 (Fla. Cir. Ct. 2011), where defense counsel Baez inquired as to why the database had not been provided to the defense (video on file in editorial offices of *SMU Science and Technology Law Review*).

> work for children.[95] Similar speculation is found throughout the forensic report which ends with a conclusion that "a portion of the total odor signature" is "consistent with an early decompositional event that *could* be of human origin" with no reference to the degree of reliability of the method or statistical significance. The report does compare the compounds detected in the trunk samples and show that all of these compounds have been detected in animal remains as well.[96]

Furton argued that there was "inadequate analysis of potential sources of the limited number of compounds reported as well as inadequate analysis of the significance of the concentrations of the compounds reported."[97] He notes that the five chemicals Vass used to argue for a decomposition event may be present in commercial products and non-human decomposition events. Therefore, Furton concluded:

> [I]t is my expert opinion that the use of characteristic chemicals to indicate a human-specific decompositional event has not been shown to be scientifically reliable to a level sufficient for use in forensic casework. At present, there is currently a lack of identified human-specific chemicals from decompositional events and an insufficient database of background materials and non-human decompositional chemicals to allow the reliability of this technique to be calculated.[98]

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95. Furton Forensic Report, *supra* note 91, at 8 (emphasis added). Fluorinated compounds in the list of thirty in Vass (2008), *supra* note 26, at 384, tbl. 2 are items 6, 10, 29, and 30. Vass's report stated:

> Common fluorinated compounds usually associated with human decomposition were not detected in the Florida trunk sample. It is possible, although this has not been studied, that a 2–3 year old child may not have had sufficient time (many years) to ingest enough fluorinated compounds for them to be incorporated into tissue and then to appear in the decompositional breakdown of soft tissue and bone.

Vass Forensic Report, *supra* note 21, at 6.

96. Furton Forensic Report, *supra* note 91, at 8.

97. *Id.*

98. *Id.* at 9; *see also* Sonja Stadler, Pierre-Hugues Stefanuto, Michal Brokl, Shari L. Forbes & Jean-Francois Focant, *Characterization of Volatile Organic Compounds from Human Analogue Decomposition Using Thermal Desorption Coupled to Comprehensive Two-Dimensional Gas Chromatography—Time-of-Flight Mass Spectrometry*, 85(2) ANALYTICAL CHEMISTRY 998, 998 (2013) [hereinafter Stadler (2013)] ("[A] comprehensive decomposition VOC profile remains elusive. This is likely due to difficulties associated with the nontarget analysis of complex samples.").

No evidence was presented as to the probability that the five remaining compounds could, on their own, indicate an odor signature of human decomposition. It is doubtful that Vass's argument could have passed any peer review without a statistical association between the compounds and the conclusion that they indicated a human decomposition event.[99]

C. Trial Judge's Analysis of Potential Evidence and Admissibility

The defense filed a motion under *Frye* to exclude as unreliable:

> [A]ny testimony or evidence concerning any alleged identification of the chemical composition of human decomposition odor, any testimony regarding a test involving elemental analysis of Laser Induced Breakdown Spectroscopy,[100] any testimony regarding quantification of chloroform, or reference to an alleged 'decompositional' odor analysis database.[101]

In addition, the defense sought to exclude testimony regarding air, carpet samples, and paper towels tested by Oak Ridge. Therein, the defense argued that the defendant's right of confrontation was violated because Oak Ridge refused to provide its database of chemical compounds relating to human decomposition to the defense.[102]

The prosecution countered that the question turned on whether the data was "gathered using generally accepted methods and interpreted using generally accepted scientific principles applied to a generally accepted body of scientific knowledge."[103] Additionally, the prosecution contended that turning over the database of chemical compounds relating to human decomposition was beyond its control since the information was proprietary to the FBI.

Judge Belvin Perry, Jr., ruling on the motion in May 2011, summarized the prosecution's response. Judge Perry stated that under *Castillo v. E.I. Du Pont De Nemours & Co.*,[104] the weight given to competing scientific views is

99. *See* Susan Haack, *Peer Review and Publication: Lessons for Lawyers*, 36 STETSON L. REV. 789, 790 (2007).

100. Laser-induced breakdown spectroscopy has only recently begun to attract any jurisprudential attention. *See* Michael T. Poulton, *Particles of What? A Call for Specificity in Airborne Particulate Regulation*, 51 JURIMETRICS J. 61, 62 (2010).

101. State v. Anthony, Case No. 48-2008-CF-15606-O (Fla. Cir. Ct. May 7, 2011) [hereinafter Perry Ruling] (order denying motion to exclude unreliable evidence).

102. *See* Cross-examination of Vass at Trial at 25:00, *supra* note 95, where defense counsel Baez inquired as to why the database had not been provided to the defense.

103. *Id.* at 2.

104. 854 So. 2d 1264, 1275 (Fla. 2003).

a matter for the trier of fact. Judge Perry denied the motion to exclude the evidence, making it admissible at trial.[105]

In reaching his decision, Judge Perry quoted *Castillo* by noting that the "purpose of *Frye* is to weed out 'junk science' from valid science and is only used when new scientific methodology is being presented. Clearly 'new' scientific methodology can be admissible when it is shown that it is not 'junk science.'"[106] Judge Perry cited *Ramirez v. State*[107] for the proposition that he had to determine three things regarding the Oak Ridge testimony, including whether: (1) it would assist the jury in understanding the evidence or in determining a fact in issue; (2) the testimony would be based on a scientific principle or discovery sufficiently established to have gained general acceptance; and (3) the particular witness was qualified as an expert to present an opinion on the subject in issue.[108]

Judge Perry noted that the parties did not disagree that no case in Florida or the United States had ever admitted evidence about "the chemical signature of the odor of human decomposition or the identity of the volatile chemical components of human decomposition . . . ."[109] Judge Perry then described Vass's qualifications and quoted from the abstract of Vass's 2004 paper. The abstract described the establishment of a Decompositional Odor Analysis Database to develop a man-portable, chemical sensor capable of detecting clandestine burial sites, "thereby mimicking canine olfaction."[110] The abstract refers to "424 specific volatile compounds associated with burial decomposition,"[111] which had become 478 by 2008 when Vass and his team produced a second paper on the topic. This number did not change in Vass's 2012 paper.[112] Vass's 2004 paper stated:

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105. Perry Ruling, *supra* note 102, at 22. The chemical evidence was not admitted with any specific requirement to be corroborative or otherwise linked to the cadaver dog evidence. It may be that defense counsel Baez, during his cross-examination of Jason Forgey, the cadaver dog handler in the investigation, was anticipating a corroboratory connection being made between the canine evidence and the chemical evidence on which Vass testified. During this cross-examination, Baez asked Forgey to confirm that he did not know what made his cadaver dog alert. Cross-examination of Forgey at *Frye* Hearing at 01:00, *supra* note 16. The possible corroborative effect of canine evidence is discussed in Ensminger & Ferguson, *supra* note 11.

106. *Id.* at 3.

107. 651 So. 2d 1164, 1166–67 (Fla. 1995).

108. Perry Ruling, *supra* note 102, at 3.

109. *Id.*

110. Vass (2004), *supra* note 57, at 760.

111. *Id.*

112. In 2012, researchers used comprehensive two-dimensional gas chromatography coupled with time-of-flight mass spectrometery (GC x GC-TOFMS) to identify 832 VOCs released by a decaying pig, and argued that this approach was sub-

> [D]efining the chemical fingerprint produced by human decomposition is an attainable goal. Success in this undertaking will advance our understanding of the scenting ability of canines and allow for the development of training aids capable of enhancing canine performance. This database is also the first step towards developing specific and reliable detection instrumentation which can be used to aid law enforcement in search-and-recovery efforts.[113]

Both the proprietary nature of the database and the commercialization of instrumentation capable of mimicking, and perhaps replacing cadaver dogs, were points of attack at trial during Vass's cross-examination.

Judge Perry determined that the initial question presented was "whether the use of the GC/MS is generally accepted in the scientific community to identify odors emanating from a decomposing human body."[114] The defense stipulated that the Vass technique could identify chemical compounds. In addition to Vass's work, Statheropoulos and his team had used GC/MS to study volatile organic compounds in early stages of human decomposition.[115] Judge Perry concluded that "[f]orensic science has recognized for over forty years the ability of the GC-MS to do just what was done by Dr. Vass—the separation and analysis of complex mixtures of volatile organic and inorganic compounds."[116] He distinguished Furton's opinion from Vass's as follows: "Dr. Furton was of the opinion that odor signatures of human decomposition were not generally accepted in the scientific community and there are no scientifically valid methods capable of identifying the presence of human remains, despite the fact he has done no research on whole body

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stantially more effective that previously applied techniques in detecting VOCs during decomposition. Jessica Dekeirsschieter, Pierre-Hugues Stefanuto, Catherine Brasseur, Eric Haubruge & Jean-Francois Focant, *Enhanced Characterization of the Smell of Death by Comprehensive Two-Dimensional Gas Chromatography-Time-of-Flight Mass Spectrometry (GCxBC-TOFMS)*, 7(6) PLOS/ONE e39005, 10 (2012) [hereinafter Dekeirsschieter (2012)]. The research, and thus the number in the FBI Database, is likely to increase as refined techniques are applied, assuming it continues to be maintained. *Id.*

113. Vass (2004), *supra* note 57, at 768. Currently popular training aids, Putrescine (1,4-Butanediamine) and Cadaverine (1,5-Diaminopentane), were named by Arpad A. Vass, *Beyond the Grave—Understanding Human Decomposition*, 28 MICROBIOLOGY TODAY 190, 190–92 (2001), as "significant decomposition products," but were not reported by Vass in subsequent research, or by anyone else. *See* Caraballo, *supra* note 31, at 190. Rosier (2015), *supra* note 59, at 2 ("[M]ostly nonspecific compounds such as cadaverine and putrescine are used to train [cadaver] dogs.").

114. Perry Ruling, *supra* note 102, at 18.

115. Statheropoulos (2007), *supra* note 80.

116. Perry Ruling, *supra* note 102, at 19.

decomposition."[117] Furton's critique, however, does not require him to have done his own experiments on whole-body decomposition. Instead, Furton's critique merely requires that he be able to evaluate the significance of a very small set of papers in determining the general acceptance of the conclusions of those papers in the scientific community.

Judge Perry cited Florida case law accepting evidence obtained by GC/MS. In *State v. Sercey*, a Florida appellate court stated that "experts agreed that GC/MS analysis is generally accepted in the scientific community" for certain types of blood analysis.[118] The judge concluded that as long as the methodology was generally accepted, as GC/MS was, opinions derived from using the methodology need not be generally accepted. Additionally, a 1998 Florida appellate case, *Berry v. CSX Transportation, Inc.*, stated that "*Frye* allows opposite opinion testimony from experts relying upon the same generally accepted scientific principles and methodologies."[119] If defects existed in Vass's interpretations, as argued by Furton, this could go to the weight of those interpretations, which need not make them inadmissible.[120] Judge Perry

117. *Id.* at 20. As discussed further below, Furton has supervised graduate students doing such research and has joined them in some subsequently published papers.

118. State v. Sercey, 825 So. 2d 959, 961 (Fla. Dist. Ct. App. 2002).

119. Berry v. CSX Transportation, Inc., 709 So. 2d 552, 567 (Fla. Dist. Ct. App. 1998).

120. Perry Ruling, *supra* note 102, at 21. The defense also moved to exclude any testimony regarding chloroform, arguing that "the state cannot 'in a new and novel manner' extrapolate findings of trace chloroform in the trunk of the Defendant's car to mean that at some point, more than a trace amounts existed or that it was connected to the death of the victim in the case." *Id.* at 4. Chloroform was identified on the spectral profile of air removed from the headspace of a metal evidence can sent by a detective in the case, as well as in a test run with cryotrapping. Vass acknowledged that he could not quantify the amount of chloroform, but said that it was the largest peak in any sample he had seen in 20 years of working in the area. The court noted Furton's criticism of the lack of quantitative analysis, arguing, in Judge Perry's words, that "it was not acceptable in forensic science or analytical chemistry for Dr. Vass to conclude that there was a large amount of chloroform." Judge Perry noted that GC/MS had been accepted under *Daubert* in *United States v. Aman*, 748 F. Supp. 2d 531 (E.D. Va. 2010), where a scientist's decision not to use comparison samples could be appropriate for cross-examination but did not constitute a basis for excluding the testimony. The court ruled that Vass's testimony regarding chloroform was also admissible under *Frye*. The latitude Florida allows experts in giving their opinions without scientific support has been an aggravation to Florida attorneys. *See generally* Neil D. Kodsi, *Trial Lawyers Forum: Confronting Experts Whose Opinions Are Neither Supported Nor Directly Contradicted by Scientific Evidence*, 80 FLA. B.J. 80 (2006); Stephen E. Mahle, *The "Pure Opinion" Exception to the Florida* Frye *Standard*, 86 FLA. B.J. 41 (2012) (arguing that, under Florida's "pure opinion" exception to *Frye* as ar-

also ruled that "Dr. Vass, based upon his background, training and experience could offer opinion testimony concerning the odor he smelled emanating from the sealed container."[121]

Thus, Judge Perry found Vass's testimony admissible under *Frye*. It passed muster under *Frye* because the instrumentation used by the Oak Ridge National Laboratory had long been used to identify chemical compounds in air samples and this type of instrumentation had been accepted by other courts. Yet the initial GC/MS analysis had demonstrated the existence of fifty-one chemicals, not the five chemicals that Vass concluded were consistent with a human decomposition event. Even if a decomposing human body is intuitively the best explanation when searching for a single source to explain the presence of the five chemicals, it is not clear that a single source is the most likely source when there had also been garbage and gas fumes present in the trunk. There are no available error rates as to either argument.[122] Judge Perry did not remark on the fact that the reduction of fifty-one to forty-one compounds was made through cross-reference to a nonpublic, non-peer-reviewed database that was unavailable to other experts. Judge Perry was also silent on the reduction from sixteen to seven compounds made solely through cross-reference to a single peer-reviewed publication of the testifying expert.

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ticulated by the Florida Supreme Court in *Marsh v. Valyou*, 977 So. 2d 543, 549 (2007), "any qualified medical expert . . . can testify to almost any causation theory, without any real judicial scrutiny.").

121. Perry Ruling, *supra* note 102, at 20.

122. It could be argued that Vass's position reflects a belief that the five chemicals more likely than not were found together in non-trace amounts because a human body had been in the trunk, while Furton's position put on this gradient would be to the effect that even such a threshold of certainty had not been established. In toxic tort causation arguments, i.e., where exposure to a chemical or product is being alleged to have caused a medical condition, courts have imposed various probability thresholds, such as that the chemical or product *more likely than not* caused the condition, or was *a substantial factor* in bringing about the condition, or that the condition would not have occurred *but for* the chemical or product. For a relatively recent discussion of causation in toxic tort litigation, a matter that has been the subject of intense debate for a quarter of a century, see generally Harvey Brown & Melissa Davis, *Eight Gates for Expert Witnesses: Fifteen Years Later*, 52 HOUS. L. REV. 1 (2014); Michael D. Green, *Causation in Pharmaceutical Cases*, SL038 ALI-ABA 139 (2005); Christopher Ogolla, *What Are the Policy Implications of Use of Epidemiological Evidence in Mass Torts and Public Health Litigation?* 23 ST. THOMAS L. REV. 157 (2010) (arguing for a heightened standard for admission). For an early discussion of expert testimony in toxic tort litigation, see generally Michael D. Green, *Expert Witnesses and Sufficiency of Evidence in Toxic Substances Litigation: The Legacy of Agent Orange and Bendectin Litigation*, 86 NW. U.L. REV. 643 (1992).

Judge Perry did not specify a probability threshold that must be present for the five chemicals at the end of Vass's analysis to establish a human decomposition event. Judge Perry merely stated Vass had found the chemicals' presence "consistent with an early decompositional event that could be of human origin" and acknowledged "the remote possibility that an unusual variety of products or materials may have had some contribution to the overall chemical signature."[123] The judge stated that the science was "not to the point where an expert will be permitted to opine that the odor signature is that *solely* of a decomposing human body."[124] Thus, any degree of probability less than absolute certainty seems to have been acceptable.

D. American Academy of Forensic Sciences

The battle of the experts, particularly between Vass and Furton, continued beyond the confines of the courtroom and took center stage at the Proceedings of the American Academy of Forensic Sciences in February 2012 (AAFS Proceedings).[125] The AAFS Proceedings refer to the case nearly thirty times, though some of those instances involve computer forensics. For one presentation entitled *Flawed Forensics: Recognizing and Challenging Misleading Forensic Evidence and Disingenuous Expert Testimony*, the program poster stated the lead defense attorney in the Casey Anthony case, Jose Baez, "will discuss the challenges he faced before and during the lengthy jury trial, as well as the methods used to impeach the forensic evidence presented by the prosecution."[126]

Baez spoke at a "Bitemark Breakfast" about how the prosecution in the Anthony case engaged in a "fantasy of forensics," that included "unverified dog alerts, false computer reports, novel science of air samples purporting to contain the odor of human decomposition,"[127] and other items that the jury was said to have seen "right through" and based on the verdict, rejected.[128]

123. Perry Ruling, *supra* note 102, at 20.

124. *Id.* at 21–22 (emphasis added).

125. AMERICAN ACADEMY OF FORENSIC SCIENCES, 18 PROCEEDINGS (Feb. 2012) [hereinafter AAFS PROCEEDINGS], http://www.aafs.org/sites/default/files/pdf/ProceedingsAtlanta2012.pdf.

126. *Id.* at 25.

127. *Id.* at 9. The trial involved some discussion of the fact that much decomposition research involved air samples above buried bodies, rather than bodies decomposing on the surface. The location of sampling can produce significantly different results. *See generally* Katelynn A. Perrault, Barbara H. Stuart & Shari L. Forbes, *A Longitudinal Study of Decomposition Odour in Soil Using Sorbent Tubes and Solid Phase Microextraction*, 1 J. CHROMATOGRAPHY A 120, 121 (2014) [hereinafter Perrault (2014)].

128. Joseph Sanders, *Scientifically Complex Cases, Trial by Jury, and the Erosion of Adversarial Processes*, 48 DEPAUL L. REV. 355 (1998) (discussing the difficulties juries may have with scientific evidence).

The title of the Breakfast, *Fantasy of Forensics: How Junk Science Failed to Persuade the Jury in the Casey Anthony Case*, was particularly aggressive.[129]

The major presentation at the Bitemark Breakfast about the trial was entitled *The Casey Anthony Trial—From the Defense, Medical, and Scientific Viewpoints*. The presenter stated despite a National Academy of Sciences (NAS) report, the judge had "allowed forensic testimony that had not been validated":[130]

> The defense claimed that much of the medical and scientific testimony was novel and had exceeded the boundaries of validated forensic science and should not have been allowed in by the gatekeeper. The judge, who did not accept the NAS Report as authoritative, allowed the jury to hear from experts whose opinions and conclusions had never been utilized in court, had not been subject to rigorous error rates, failed to have peer review protocols or quality control, and appeared to fall short of United States Supreme Court standards.[131]

129. AAFS PROCEEDINGS, *supra* note 126, at 9. Although this article argues that the admission of Vass's testimony regarding the chemical evidence for a human decomposition event exceeded the best law on admissibility, the authors take exception to the characterization of Vass's work or testimony as "junk science." Vass did not avail himself of "maverick methodologies" in reaching his conclusions. *See* Elizabeth R. Gonzalez, Comment, *Whither "Junk Science"?*, Daubert v. Merrell Dow *and the Future of Expert Testimony*, 26 J. HEALTH & HOSP. L. 296, 7 (1993). For a legal article that seemingly accepts the description of Vass's testimony as junk science, see generally William Giacomo, *Scientific Proof Versus Junk Science: The Court's Role as Gatekeeper for Admitting Scientific Expert Testimony*, 41 WESTCHESTER B.J. 29 (Spring 2016).

130. AAFS PROCEEDINGS, *supra* note 126, at 4.

131. *Id.* Regarding error rates, Green & Sanders conclude:

> Error rate, on the other hand, has played a very limited role in judicial discussions of general causation. This is not because studies used to assess general causation do not contain error rates. All research, indeed all decisions have error rates . . . . In other cases, courts throw in the observation that the expert has not identified an error rate as a makeweight to a decision already made to exclude the expert's opinion.

Michael D. Green & Joseph Sanders, *Admissibility versus Sufficiency: Controlling the Quality of Expert Witness Testimony*, 50 WAKE FOREST L. REV. 1057, 1070 (2015). Meixner & Diamond note that "the *Daubert* Court itself seemed to deemphasize the error rate factor as compared to the [other *Daubert* factors]." John B. Meixner & Shari S. Diamond, *The Hidden* Daubert *Factor: How Judges Use Error Rates in Assessing Scientific Evidence*, 2014 WIS. L. REV. 1063, 1070 (2014):

> [M]ajor questions of how to deal with error rates were entirely ignored in *Daubert*. Although the Court said that lower courts should "consider" the known or potential rate of error, it did not specify whether lower courts

Clearly, the presenters believed that the judge should have known better.

The NAS report referred to in the AAFS presentation by defense counsel in the Anthony trial stated that "[f]orensic science reports, and any courtroom testimony stemming from them, must include clear characterization of the limitations of the analyses, including associate probabilities where possible."[132] The NAS report criticized courtroom evidentiary practices by noting that much forensic evidence "is introduced in criminal trials without any meaningful scientific validation, determination of error rates, or reliability testing to explain the limits of the discipline."[133] Furthermore, the report observed "even those forensic science disciplines whose scientific foundation is currently limited might have the capacity (or the potential) to provide probative information to advance a criminal investigation."[134] This is an important observation because some disciplines, such as canine scent identification—where the methodology used may not be sufficiently reliable for use in a courtroom—can still point the investigators in a direction that will lead to other, more reliable, evidence. However, if that does not occur, the prosecutor must determine whether the effort should be made to advance the case with evidence that may be unacceptable to a judge or so vulnerable to a defense attack that the case will collapse.

> should (1) examine the rate of error to determine whether it stays underneath some unknown threshold, above which the factor cuts against admissibility . . . or (2) simply ascertain whether an accurate rate of error has been produced, leaving the trier of fact to assess the probative value of the evidence in light of that error rate . . . .

Id. at 1073–74. Judge Perry made no mention of "error rate" in his *Frye* ruling, nor did Vass in his report. Furton discussed the impossibility of calculating error rates from Vass's data or for determining "the likelihood of false positive and false negatives under the conditions employed." Furton Forensic Report, *supra* note 91, at 8. Meixner & Diamond argue, however, that a court's analysis may be directed at an "implicit error rate."

> [J]udges . . . will spend significant time talking about the dependability of the methods used by an expert, whether the conclusions made by the expert align with those methods, whether those methods seem sound, and so forth. In doing this, the judge, though not explicitly discussing a specific error rate, is trying to determine the likelihood that the expert's opinion is distorted by weaknesses in methodology, revealing an implicit error rate problem.

Meixner & Diamond, *supra* at 1080–81. A number of the steps in Figure 1 herein could not be said to have determinable error rates.

132. NAT'L RES. COUNCIL, COMMITTEE ON IDENTIFYING THE NEEDS OF THE FORENSIC SCIENCE COMMUNITY, STRENGTHENING FORENSIC SCIENCE IN THE UNITED STATES: A PATH FORWARD 186 (2009).

133. *Id.* at 107–08.

134. *Id.* at 127.

III. CONTINUING SEARCH FOR A DECOMPOSITION ODOR PROFILE

Researchers continue to search for a decomposition odor profile with varying degrees of success:

> DeGreeff & Furton note "a huge discrepancy in the reported compounds between different research groups." They state that their "work is the first to report VOCs obtained from a population of 27 individuals [cadavers] from multiple locations to determine similar volatiles." In summarizing this paper in a subsequent review paper, Furton, in 2015, said that the comparison of human scent from living individuals differed from that collected from deceased remains in that with respect to the deceased remains "there was less variation between subjects signifying a more generalized odour."[135]

However, reduced variation in comparison of scent from living humans is far from a claim to have identified an odor profile of human decomposition.[136]

> Agapiou recently argued, in the context of establishing a VOC profile for search and rescue applications, that "significant effort and progress . . . is impeded because many studies report large numbers of candidate VOCs, are based on small numbers of participants, and use different analytical technologies, and standardized approaches to sampling data, normalization and validation have yet to be adopted.".[137]

For example, Perrault's 2014 paper states:

> Inconsistencies exist in the VOC profiles reported in published literature, which reflects variations in decomposition variables (environment, weather, soil type, cadaver/carcass size, geographical location *etc.*) and/or analytical methods (collection technique, instrument used, instrument parameters, *etc.*) used in these studies. Variation-inducing factors are often associated with outdoor decomposition environments involving soil.[138]

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135. Ensminger & Ferguson, *supra* note 11, at 117–18 n.17 (internal citations omitted).

136. Kenneth G. Furton, Norma Iris Caraballo, Michelle M. Cerreta & Howard K. Holness, *Advances in the Use of Odour as Forensic Evidence Through Optimizing and Standardizing Instruments and Canines*, 370 PHIL. TRANS. R. SOC. B.: BIOLOGICAL SCI. 1, 10 (2015).

137. Ensminger & Ferguson, *supra* note 11, at 117–18 n.17 (internal citations omitted).

138. *Id.* at 117–18 n.17 (quoting Perrault (2014), *supra* note 128, at 121; *see also* Sonja Stadler, Pierre-Hugues Stefanuto, Jonathan D. Byer, Michal Broki, Shari Forbes & Jean-Francois Focant, *Analysis of Synthetic Canine Training Aids by*

The classification of variables into those related to the decomposition environment and those related to analytical methods is particularly useful.[139] Decomposition-related variables cannot be controlled for in a forensic setting; in addition to those mentioned in the above passage, time since death, whether the body was buried, wrapped, or accessible to insects, and aerobic or anaerobic decay conditions, should be considered.[140] The effects of these variables must be taken into account in considering whether a particular set of compounds establishes a human decomposition event. With respect to analytical methods, standardizing, at a minimum, the sample collection procedure could bring more data into alignment. Perrault considered disparities in sample collection among different studies:

> Sorbent-based methods such as sorbent tubes and solid phase microextraction (SPME) are commonly employed in the field of decomposition VOC research due to their widespread and standardised use for environmental monitoring. General ranges for sorbent specificity are often indicated by manufacturers and in the literature, yet the sorbents commercially available for each technique are not equivalent to each other. The prevalence of sorbent-based methods in decomposition odour analysis prompts the issue of potential bias of results associated with the use of a single collection technique or sorbent.[141]

After comparing VOCs collected from decomposing pig carcasses using both sorbent tubes and SPME, this team found the number of VOCs identified only by using sorbent tubes, only by SPME, and by both were forty-seven, forty-six, and thirty-six, respectively, and that different classes of chemical compounds were often favored by one or the other technique.[142] Considering that less than one third of all detected compounds were found using both techniques on identical decomposition subjects, it comes as no surprise that studies that differ both in decomposition variables and analytical sampling techniques often produce disparate data.

Despite the many uncertainties in comparing studies, some compounds and quantities of VOCs found in human decomposition have been noted as differing from that of animal decomposition. Vass states:

Comprehensive Two-Dimensional Gas Chromatography-Time of Flight Mass Spectrometry, 1255 J. CHROMATOGRAPHY A 202, 202–06 (2012); B.B. Dent, S.L. Forbes & B.H. Stuart, *Review of Human Decomposition Processes in Soil*, 45 ENVT'L. GEOLOGY 576, 576–85 (2004) [hereinafter Dent (2004)].

139. *See* Perrault (2014), *supra* note 128, at 121.

140. *See* Dent (2004), *supra* note 139, at 584.

141. Perrault (2014), *supra* note 128, at 122.

142. *Id.* at 126.

> [W]hen animal carcass VOCs are analyzed, 2-methyl butanal is always greater than 3-methyl butanal (this trend is also seen in animal fecal samples). This is reversed (or equal – within 10% in one instance) in human remains and is potentially a key marker to determine if the remains are human or not, especially in older gravesites.[143]

Rosier found, however, that "3-methylbutanal was detected more frequently than 2-methylbutanal *in both human and animal remains*."[144] DeGreeff and Furton concluded that styrene and benzoic acid methyl ester "were the only two compounds found in all human remains samples, but not in any animal remains samples."[145] Since Vass's testing of the trunk sample was not quantified, the proportions of 2- and 3-methyl butanal were not determined, and the two compounds mentioned by DeGreeff and Furton were not detected from the carpet sample.[146]

> Rosier et al. (2015) examined decomposition of 6 human cadavers, one pig, and a host of other mammals, fish, amphibians, reptiles, and birds in a laboratory setting over a six-month period. Human and pig remains were separated by organ and tissue types, whereas the smaller animal carcasses were left intact. Human and pig remains could be distinguished from all other animal remains using a combination of eight VOCs. Despite the similarity in VOC composition between decomposing human and pig remains, the authors found that the pig and human data could be distinguished based on a combination of five esters.[147]

However, Rosier (2015) stressed "[a]dditional research in the field has to corroborate these results in order to see if the environmental parameters influence the release of these compounds and if they are also seen in the VOC-profile of full bodies."[148]

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143. Vass, *Odor Mortis*, *supra* note 17, at 239.

144. Rosier (2015), *supra* note 59, at 10, tbl. 4 (emphasis added).

145. DeGreeff & Furton (2011), *supra* note 80, at 1306. Despite identifying 832 compounds in pig decomposition, Dekeirsschieter confirmed that these two compounds were not among those found by their improved sampling technique. *See* Dekeirsschieter (2012), *supra* note 113, at 9.

146. Styrene was detected in the garage air, according to Vass Forensic Report, *supra* note 21, at 3.

147. Ensminger & Ferguson, *supra* note 11, at 111; *see* Rosier (2015), *supra* note 59, at 12 (listing the five esters as: 3-methylbutyl pentanoate, 3-methylbutyl 3-methylbutyrate, 3-methylbutyl 2-methylbutyrate, butyl pentanoate, and propyl hexanoate).

148. Rosier (2015), *supra* note 59, at 13.

A new analytical technique that promises identification of more VOCs at lower detection limits is GC x GC-TOFMS.[149] The premise here is that, after passing through a single GC column, some VOCs are not sufficiently separated from similarly eluting compounds.[150] Consequently, this results in several VOCs yielding one sample peak, which can either be identified as a single compound or not properly identified as any of the constituent compounds because the hybrid MS signal fails to match any one compound.[151] However, adding a cryofocusing element after the first GC column, followed by a second GC column, allows for much better separation and detection.[152] Unfortunately, the degree of complexity of the data is substantially increased as well. Stefanuto used this instrumental technique for an early stage decomposition (six days) comparison between human and pig remains, but the authors concluded that further data analysis was necessary to pinpoint a human-specific decomposition signature.[153] Thus, difficulty of data analysis may be the most significant hurdle in furthering the understanding of the human decomposition odor profile, as communicated in a recent review on forensic applications of GC × GC-TOFMS:

> Given these powerful opportunities for using GC × GC in criminal investigations, the so far modest use of this analytical technology in forensic laboratories must be related to current limitations with respect to the expensive equipment and analytical expertise required and to the limited functionality of the software to process and analyze the complex 3D datasets. The insight that further progress in data treatment and analysis is required to advance GC × GC is indeed not new and not restricted to forensic science; it has been communicated by many analytical chemists.[154]

149. *See, e.g.*, Dekeirsschieter (2012), *supra* note 113. This study, however, used a suction pump to draw in 60 liters of air over an hour next to a dead pig, inevitably collecting and identifying substantially more compounds than would be the case with passive VOC collection.

150. *See id.* at 1–2.

151. *See id.*

152. *See id.*

153. *See* Pierre-Hugues Stefanuto, Katelynn A. Perrault, Sonja Stadler, Romain Pesesse, Helene N. LeBlanc, Shari L. Forbes & Jean-Francois Focant, *GC x GC-TOFMS and Supervised Multivariate Approaches to Study Human Cadaveric Decomposition Olfactive Signatures*, 407(6) ANALYTICAL & BIOANALYTICAL CHEM. 4767 (2015).

154. Andjoe Sampat, Martin Lopatka, Marjan Sjerps, Gabriel Vivo-Truyols, Peter Schoenmakers, & Anrian van Asten, *The Forensic Potential of Comprehensive Two-Dimensional Gas Chromatography*, 80 TRAC TRENDS IN ANALYTICAL CHEMISTRY 345 (2016).

Given the growing number of decomposition studies being conducted and the recognition that sampling techniques can alter the types or amounts of VOCs identified, it seems reasonable to assume that at some point in the future a human decomposition odor profile will be established and accepted by the scientific community. Such a level of acceptance should result in judicial acceptance as well.[155] There are also indications that not only may an odor profiles for human decomposition be developed, but also that such forensics may be able to distinguish between profiles of specific individuals, which would be important in crimes with multiple corpses where the locations of specific corpses prior to discovery may be important.[156]

IV. JUDICIAL ANALYSIS OF COMPLEX SCIENTIFIC PROCEDURES

To determine whether Judge Perry properly applied *Frye*'s reasoning, or whether his analysis would satisfy *Daubert*, it is necessary to review how courts have looked at expert testimony in cases where scientific evidence was produced by multiple steps, including statistical analysis.

A. The *Frye* Tradition

In *Frye*, the District of Columbia Circuit held that "the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs."[157] In the current context, the deduction includes forty-one of the fifty-one chemicals identified by the GC/MS procedure as being consistent with a human decomposition event. Further, the additional deduction of seven of the remaining chemicals after excluding those that could be present in gasoline or in controls were important in determining the existence of a decomposition event. Such a deduction must be said to have been made on data filtering procedures *not* "sufficiently established to have gained general acceptance in the particular field" to which the analysis belongs.[158]

155. Chemical analysis of cadavers may also be useful in determining cause of death. *See* V. Varlet, F. Smith, N. Guiliani, C. Egger, A. Rinaldi, A. Dominguez, C. Chevalier, C. Brugier, M. Augsburger, P. Mangin & S. Grabherr, *When Gas Analysis Assists with Postmortem Imaging to Diagnose Causes of Death*, 251 FORENSIC SCI. INT'L 1, 1–10 (2015) (describing how gas embolism from a scuba diving accident could be distinguished from gas embolism from a traumatic injury).

156. *See* Jessica S. Brown, Paola A. Prada, Allison M. Curran & Kenneth G. Furton, *Applicability of Emanating Volatile Organic Compounds from Various Forensic Specimens for Individual Differentiation*, 226 FORENSIC SCI. INT'L 173 (2013).

157. Frye v. United States, 293 F. 1013, 1014 (D.C. Cir. 1923).

158. *See id.*

In *Berry v. CSX,* which Judge Perry subsequently cited in support of admitting the evidence, the Florida appellate court noted that the "validity of scientific conclusions is often based upon the replication of research findings, and consistency in these findings is an important factor in making a judgment about causation."[159] In *Cadarian v. Merrell Dow Pharmaceuticals, Inc.*, a single study could not support an expert's opinion where "the study's authors themselves concluded that the results could not be interpreted without independent confirmatory evidence."[160] In Vass's 2004 paper, the researchers spoke of defining the chemical fingerprint produced by human decomposition as an attainable goal.[161] Later, a 2008 paper by the same group argues for additional research to determine if trained canines respond to the thirty compounds identified in the study.[162] The researchers also claim that further analytical tools and methodologies will help in identifying clandestine burial sites.[163] Vass's 2012 paper, *Odor Mortis*, argues "[s]ignificant additional research must be performed" to explain odor mortis.[164] *Odor Mortis* further acknowledges that "[c]urrently it is not yet possible to accurately predict which compounds will be present at any given decompositional event since the mechanisms of compound formation and the taphonomic influences are not yet fully understood."[165]

The Seventh Circuit held in *Cella v. United States*, that "the *Frye* standard requires that the methodology *and reasoning* used by an expert in reaching a conclusion be generally accepted within the relevant scientific community."[166] Nevertheless, Judge Perry was satisfied with the methodology being generally accepted without an analysis of the reasoning.[167] That is,

159. Berry v. CSX Transportation, Inc., 709 So. 2d 552, 559 (Fla. Dist. Ct. App. 1998) (citing Kehm v. Proctor & Gamble Co., 580 F. Supp. 890, 901 (N.D. Iowa 1982) (noting the persuasive power of multiple independent studies, each of which reached the same finding of an association between the toxic shock syndrome and tampon use)).

160. Cadarian v. Merrell Dow Pharm., Inc., 745 F. Supp. 409, 412 (E.D. Mich. 1989).

161. . Vass (2004), *supra* note 57, at 768.

162. Vass (2008), *supra* note 26, at 390.

163. *Id.*

164. Vass, *Odor Mortis*, *supra* note 17, at 240.

165. *Id.*

166. Cella v. United States, 998 F.2d 418, 425 (7th Cir. 1993) (emphasis added).

167. David L. Faigman, John Monahan & Christopher Slobogin, *Group to Individual (G2i) Inference in Scientific Expert Testimony*, 81 U. CHI. L. REV. 417, 427 (2014) [hereinafter Faigman (2014)] (noting the general acceptance language in *Frye* is "famously ambiguous" because, among other things, "it leaves unclear precisely what must be generally accepted (the general methodology behind the expert's testimony, the way in which the expert applied the methodology, or both) . . . ."). Here, Judge Perry was satisfied with the general acceptance of the

the methodology produced a list of fifty-one chemicals, while the reasoning that reduced this list to five before a conclusion was reached as to whether the five chemicals were consistent with a human decomposition event.[168]

Although Judge Perry partially relied on *Berry v. CSX*, it is not clear whether this reliance can be justified given the *Berry* court's reliance on *Brim v. Florida*, which was a challenge to DNA test results that included statistical analysis.[169] In *Brim*, the Florida Supreme Court held that a statistical step was needed to "give significance to a match."[170] This decision overturned a lower court decision, which had held that population frequency statistics applied after chemical analysis of DNA did not need to satisfy the *Frye* test.[171] But *Brim*'s newly articulated test required the statistical step to satisfy *Frye*:

> This second step of the DNA testing process does not rely upon principles of molecular biology or chemistry. Instead, the calculation of population frequency statistics is based on principles of statistics and population genetics. Accordingly, calculation techniques used in determining and reporting DNA population frequencies must also satisfy the *Frye* test. It is clear that the DNA testing process consists of two distinct steps and that both steps must satisfy the requirements of *Frye*.[172]

Brim also considered whether multiple statistical calculations could simultaneously satisfy *Frye*, and concluded that it was appropriate to "allow multiple reasonable deductions when *all* are based on generally accepted principles of population genetics and statistics."[173] Here, Judge Perry at-

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general methodology. Liz Heffernan, *The Reliability of Expert Evidence: Reflections on the Law Commission's Proposal for Reform*, 73 J. CRIM. L. 488 (2009), writing from the perspective of an English jurist looking at American evidentiary law, correctly notes that in the United States, the "general acceptance test was sufficiently malleable that it could be pursued with rigour, applied perfunctorily as a matter of form or sidestepped altogether." David L. Faigman, *Mapping the Labyrinth of Scientific Evidence*, 46 HASTINGS L.J. 555 (1995), continues to be valuable in understanding the complexity of scientific evidence in legal contexts.

168. How courts treat statistical significance from scientific studies is itself a complex area of legal analysis. *See* Margaret A. Berger, *Upsetting the Balance Between Adverse Interests: The Impact of the Supreme Court's Trilogy on Expert Testimony in Toxic Tort Litigation*, 64 L. & CONTEMP. PROBS. 289, 289–326 (2001).

169. Brim v. State, 695 So. 2d 268, 269–70 (Fla. 1997).

170. *Id.* at 269.

171. *Id.*

172. *Id.* at 270.

173. *Id.* at 273 (emphasis added).

tempted to give significance to the results that could not satisfy *Frye* by comparing the sixteen remaining chemicals—after eliminating those that were not within the confidential database and those that were found within controls—against the list of thirty chemicals *most important for human decomposition*. There were—as Furton correctly argued as a defense expert—no error rates in the results provided by Vass in his expert report. Additionally, the comparisons in the argument were not made against generally accepted statistics relevant to human decomposition events.

B. Expansion of Relevant Factors for Admissibility Under *Daubert*

It is also appropriate to consider Justice Blackmun's opinion in *Daubert* in this context. *Daubert* held that Rule 702 of the Federal Rules of Evidence superseded *Frye* for federal courts.[174] The case has also been adopted by a number of state courts, including Florida,[175] as a means of evaluating the admissibility of scientific evidence. Justice Blackmun stated that "the trial judge must ensure that any and all scientific testimony or evidence admitted is not only relevant, but reliable."[176] Reliability of a principle means that its application produces consistent results. But evidentiary reliability is based on scientific validity, such as a principle that supports what it purports to show.[177] Whether scientific knowledge "will assist the trier of fact to understand or determine a fact in issue . . . entails a preliminary assessment of whether the reasoning or methodology underlying the testimony is scientifically valid and of whether that reasoning or methodology properly can be applied to the facts in issue."[178] Justice Blackmun weighed a non-exclusive list of factors in making such an inquiry. Justice Blackmun's factors include:

1. Whether a theory or technique can be or has been tested.[179]
2. Whether the theory or technique has been subjected to peer review or publication.[180]

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174. Daubert v. Merrell Dow Pharm., 509 U.S. 579, 597–98 (1993).

175. Fla. H.B. 7015 (enacted June 4, 2013), amending FLA. STATS., Title VII, Chapter 90 (Evidence), section 90.702 (testimony by experts) and 90.704 (basis of opinion testimony by experts). The preamble to the bill states, "the Florida Legislature intends to adopt the standards for expert testimony in the courts of this state as provided in *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579 (1993), *General Electric Co. v. Joiner*, 522 U.S. 136 (1997), and *Kumho Tire Co. v. Carmichael*, 526 U.S. 137 (1999), and to no longer apply the standard in *Frye* . . . in the courts of this state . . . ." *Id.*

176. *Daubert*, 509 U.S. at 589.

177. *Id.* at 590, n.9.

178. *Id.* at 592–93.

179. *Id.* at 593.

180. *Id.*

3. Known of potential rate of error.[181]

4. Existence and maintenance of standards controlling the technique's operation.[182]

5. Degree of acceptance in the scientific community.[183]

Justice Blackmun noted that, while "submission to the scrutiny of the scientific community is a component of 'good science,'" some propositions "are too particular, too new, or of too limited interest to be published."[184] He also noted that skepticism may be appropriate where there is only minimal support within the scientific community. Justice Blackmun emphasized that the "focus, of course, must be solely on principles and methodology, not on the conclusions that they generate."[185] Even if relevant, evidence can be excluded under Rule 403 "if its probative value is substantially outweighed by the danger of unfair prejudice, confusion of the issues, or misleading the jury . . . ."[186]

In assessing the validity of Vass's reasoning and methodology with the five non-exclusive factors listed by Justice Blackmun, it could be said that GC/MS has been tested as a technique, and Vass's theory as to how the data could be filtered could be said to have received some peer review and publication in Vass's 2008 paper. The 2008 paper, however, does not identify any potential rate of error and is only limitedly accepted in the scientific community. Meixner and Diamond noted *Daubert* "did not specify how broadly the error rate of a method should be defined," and it might apply only to the "overall technique broadly" or at "the error rate of the individual expert testifying."[187] For the GC/MS evidence provided by Vass, error rates could be considered desirable yet missing at numerous steps: (1) the analytical techniques applied to produce the fifty-one chemicals identified from the trunk sample; (2) the assumed comprehensiveness and comparative value of the confidential database; (3) the assumed comprehensiveness of the negative controls; and (4) the accuracy of the determination of the thirty significant

181. *Id.* at 594.

182. *Daubert*, 509 U.S. at 594.

183. *Id.*

184. *Id.* at 593.

185. *.Id.* at 595. Applying such a sentence to Vass's evidence in the Casey Anthony prosecution is made difficult by the question of where "principles and methodology" stop and where the "conclusions that they generate begin." The authors believe that the multiple steps described in Figure 1, *supra*, are more appropriately considered part of the methodology than a string of interconnected conclusions.

186. *Id.* A significant difference between *Frye* and *Daubert* is that while the former concerned novel scientific methods, the latter also applied to existing scientific methods. *See* Eric Nielson, *The Admission of Scientific Evidence in a Post-*Crawford *World*, 14 MINN. J.L., SCI. & TECH. 951 (2013).

187. Meixner & Diamond, *supra* note 132, at 1070.

compounds for human decomposition events. Meixner and Diamond correctly note the connection of error rate to the conclusions reached by an expert:

> [W]hile the broad view of the error rate factor considers the likelihood that the expert's conclusions will be erroneous, it bases that likelihood on the quality of the expert's methods themselves, in the same way an explicit error rate gives the likelihood that the expert's conclusions will be erroneous based on past empirical testing. Thus, the only reason any analysis of the expert's methods is relevant to admissibility is in light of the conclusions that the expert is likely to generate; reliable methods are not an end in themselves, but rather a means to the end of achieving valid conclusions to present to the trier of fact.[188]

Thus, to apply an error rate solely to the first step in Vass's process hardly establishes the reliability of his conclusions. The filtering steps must also be supported in order for those conclusions to have sufficient reliability for the conclusions reached by Vass.

B. Analytical Gaps Between Data and Opinion Under *Joiner*

In *General Electric Co. v. Joiner*, the U.S. Supreme Court—in an opinion authored by Chief Justice Rehnquist—reversed the Eleventh Circuit and held that the district court had not abused its discretion in finding "too great an analytical gap between the data and the opinion proffered" by experts.[189] A court is not required "to admit opinion evidence that is connected to existing data only by the *ipse dixit* of the expert."[190] Thus, as argued by Bern-

188. *Id.* at 1073, n.28.

189. General Electric Co. v. Joiner, 522 U.S. 136, 146 (1997). The Chief Justice's opinion included a general caution as to appellate review in chiding the 11th Circuit for failing to give the trial court "the deference that is the hallmark of abuse of discretion review." *Id.* at 143. As already noted, criticizing the ruling of Judge Perry in the Casey Anthony case is not an argument that it would necessarily have been overturned had the matter reached an appellate level. As noted by Caudill & LaRue, "sometimes science is less than certain, sometimes scientists necessarily piece together a probable series of events under less than ideal circumstances, and sometimes their admissible conclusions are shaky, challengeable, or less persuasive than at other times." David S. Caudill & Lewis H. LaRue, *Why Judges Applying the* Daubert *Trilogy Need to Know About the Social, Institutional, and Rhetorical—and Not Just the Methodological—Aspects of Science*. 45(1) BOS. C.L. REV. 1, 28 (2003).

190. *General Electric Co.*, 522 U.S. at 146. Faigman (2014), *supra* note 168, at 429 (noting this sentence "suggests that a court's gatekeeping obligations [with regard to scientific evidence] extend to all components of an expert's proposed testimony, from the most general to the most specific.").

stein, *Joiner* meant "courts may scrutinize the reliability of an expert's reasoning process as well as the general methodology."[191]

Judge Perry's analysis relied on finding that other courts view mass spectrometry and gas chromatography as "extremely reliable."[192] But Judge Perry never considered whether Vass's steps eliminating forty-four compounds from consideration—and the general lack of quantification of any compounds—could leave enough data to support the argument that a likely explanation for the presence of five chemicals in the trunk sample was that a human decomposition event had occurred there. There was, in other words, a substantial "analytical gap" between the initial raw data and the conclusion that would fail under a *Joiner* analysis.[193]

Although *Joiner* was an extension of *Daubert*, a strong argument could be made that the "analytical gap" analysis would also apply to testimony being reviewed under *Frye*. Chief Justice Rehnquist stated in *Joiner* "the Federal Rules of Evidence allow district courts to admit a somewhat broader range of scientific testimony than would have been admissible under *Frye*

191. David E. Bernstein, Frye, Frye, *Again: The Past, Present, and Future of the General Acceptance Test*, 41 JURIMETRICS J. 385, 386 (2001). The Oregon federal district court may have carried this further by saying that it would "examine the evidence to ensure . . . that *every* step in the expert's reasoning process, including the expert's formulation of conclusions, are grounded in good science." Hall v. Baxter Healthcare Corp., 947 F. Supp. 1387, 1401 (1996). The distinction between methodology and conclusion is not always evident. *See* M.J. Saks, *The Aftermath of* Daubert*: An Evolving Jurisprudence of Expert Evidence*, 40 JURIMETRICS J. 229 (2000).

192. Perry Ruling, *supra* note 102, at 17–18 (citing Missouri v. Price, 731 S.W.2d 287 (Mo. Ct. App. 1987)).

193. Brown & Davis, *supra* note 123, at 260 (noting that there may be several types of analytical gaps in arguments of experts, e.g., between "the underlying data, facts, or assumptions and the opinion," or "between the expert's methodology and the opinion."). The authors stated:

> When the expert's reasoning from premise to conclusion includes a leap of faith, the leap, if big enough, necessitates exclusion of the opinion as an improper extrapolation regardless of whether the premise is a methodology, technique, or data relied on by the expert . . . . And even if the opinion is admitted without objection, the opinion may be deemed conclusory and therefore "no evidence."

Id. Brown & Davis acknowledge, however, that sometimes the presence of analytical gaps goes to the weight to be given evidence, not its admissibility. *Id.* at 19. Arguably there was an analytical gap in Vass's argument in that he failed to explain why a single-source (decomposing body) was necessarily more likely than multiple sources (cleaning and other products) to explain the chemical mixture identified from the trunk sample.

. . . ."[194] If that is a broad perspective of the distinction between *Frye* and *Daubert*, then the general acceptance requirement of *Frye* makes it, if anything, even harder to bridge analytical gaps. For example, in *Christophersen v. Allied-Signal Corp.*, the Fifth Circuit applied *Frye*.[195] The court concluded if an expert's mode of reasoning is not "sufficiently established to have gained general acceptance in the particular field in which it belongs," then it is to be excluded as evidence.[196] Further, if what science offers is essentially "no more than theoretical speculation, then well-founded methodology and reasoning may not alone suffice."[197]

In 2007, Craig Smith noted "it is not inconsistent with *Daubert*, *Kumho Tire [v. Carmicheal]*,[198] and Federal Rule of Evidence 702 for an expert to rely on statistical percentages, risk coefficients, and other probabilistic evidence in formulating an opinion on causation."[199] If the causation in Casey Anthony's case is the source of the five compounds that were left for analysis after the various elimination steps were applied, then it must be acknowledged that Furton's expert report correctly observes that Vass's methods do not allow for making "scientific conclusions with reasonable degrees of scientific certainties using established statistical techniques."[200] If *Daubert* and

194. *General Electric Co.*, 522 U.S. at 142. It must be acknowledged that the remainder of this partially quoted sentence refers to the trial judge's discretion as a gatekeeper.

195. Christophersen v. Allied-Signal Corp., 939 F.2d 1106, 1111 (5th Cir. 1991).

196. *Id.* (internal quotations omitted).

197. *Id.* For a convincing argument that "case law under *Frye* is slowly converging with *Daubert* jurisprudence," see Bernstein, *supra* note 192, at 398.

198. *Daubert*, *Joiner*, and *Kumho Tire* are sometimes referred to as making up a trilogy of Supreme Court scientific evidence cases. *See* Caudill & LaRue, *supra* note 190, at 3.

199. Craig Smith, *Peering into the Microscope: The Rise of Judicial Gatekeeping after* Daubert *and Its Effect on Federal Toxic Tort Litigation*, 13 BOS. U.J. SCI. & TECH. L. 218, 225 (2007). Causation in a criminal case, such as the prosecution of Casey Anthony, and a civil case, such as toxic tort litigation, should arguably be distinguished. Cranor & Eastwood argue that "judicial principles must be crafted to permit expert testimony as early as practicable in the history of the discovery of toxic properties [or] actual victims of toxic exposures will have no redress against those responsible . . . ." Carl F. Cranor & David A. Eastmond, *Scientific Ignorance and Reliable Patterns of Evidence in Toxic Tort Causation: Is There a Need for Liability Reform?*, 64 L. & CONTEMP. PROBS. 5, 24 (2001). This argument is less appealing in a criminal context where society's interests are being balanced against those of a defendant.

200. Furton Forensic Report, *supra* note 91, at 8. Expertise for admission of testimony may involve that the witness not merely be qualified in a single field, but may also require that he or she have expertise to interpret results statistically. *See* James R. Ehrlinger & Scott M. Matheson, *Stable Isotopes and Courts*, 2010(2) UTAH L. REV. 385–442 (2010).

its progeny required an "expert's testimony may only be admitted if the expert can establish through scientific evidence that his causal hypothesis has been reliably tested and validated," as stated by Joe G. Hollingsworth and Eric G. Lasker, then the testimony should not have been admitted under that standard.[201]

C. Federal Rule 702

Leaving aside the case law and merely looking at federal evidentiary guidelines, Rule 702 states that an expert's testimony must be based on "sufficient facts or data," and be "the product of reliable principles and methods," with those principles and methods "reliably applied" to the facts of the case.[202] Reliable application appears to require analytical gaps be bridged by steps that are each reviewed under the five *Daubert* criteria (testing, peer review or publication, rate of error, standards controlling technique's operation, acceptance in the scientific community).[203] This might be indicated by *Kumho Tire Co. v. Carmichael*, where Justice Breyer said that *Daubert*'s gatekeeping requirement was "to make certain that an expert, whether basing testimony upon professional studies or personal experience, employs in the courtroom the same level of intellectual rigor that characterizes the practice of an expert in the relevant field."[204] It would seem that the application of statistical methods, unsupported by any information other than that of the researcher testifying, lacks the necessary "intellectual rigor that characterizes the practice of an expert . . . ."[205]

In *Magistrini v. One Hour Martinizing Dry Cleaning*, a federal district court analyzed an expert's evidence under *Daubert* and stated where "elements of judgment pervade the methodology, it is essential that the expert set forth the method for weighing the evidence upon which his opinion is based."[206] Vass did not provide the database from which the first culling of

201. Joe G. Hollingsworth & Eric G. Lasker, *The Case Against Differential Diagnosis:* Daubert, *Medical Causation Testimony, and the Scientific Method*, 37(1) J. HEALTH L. 85, 90 (2004). Also note that association is not equivalent to causation because it might result from bias or chance.

202. FED. R. EVID. 702.

203. Daubert v. Merrell Dow Pharmaceuticals, 509 U.S. 579, 593–94 (1993).

204. Kumho Tire Co. v. Carmichael, 526 U.S. 137, 152 (1999).

205. For the impact of *Kumho Tire*, see Chin Kuay, Comment, *Ten Years after Arkansas Adopted* Daubert*: Anything New under the Sun?* 65 ARK. L. REV. 65, 409, 418 (2012) ("After *Kumho*, federal courts are obliged to apply a *Daubert* analysis to all categories of expert testimony, whether based on scientific, technical, or other specialized expertise. Commentators have noted that Joiner and *Kumho* have extended the width and depth of *Daubert* in such a way that it has been transformed into a test stricter than *Frye* ever was.").

206. Magistrini v. One Hour Martinizing Dry Cleaning, 80 F. Supp. 2d 584, 608 (2002).

the list of chemicals was made. Therefore, he could not fully set forth the method for weighing that treatment of the evidence in any way that another expert, or a judge or juror could evaluate. The evidence should, therefore, have been excluded under the Federal Rules of Evidence, and Florida's current statutory provisions regarding scientific evidence.[207]

V. IMPLICATIONS OF DECOMPOSITION RESEARCH FOR CADAVER DOGS

Many scholarly papers on the chemistry of human decomposition refer to the research as being relevant to understanding what cadaver dogs smell when alerting investigators.[208] Given the number of chemicals being detected and the variable quantities of those chemicals that appear in different environments—particularly as to aerobic and anaerobic decomposition[209]—it is unlikely that more can be understood about what the dogs are detecting without actual research. Such research would have to involve presenting dogs with different combinations of chemicals, in different concentrations, to determine the variability of the chemical profile of decomposition that is meaningful to the canine olfactory sense.[210] The combinations and concentrations of decomposition chemicals that dogs detect may not be—indeed, are unlikely to be—identical to the full profile determined by sophisticated chemical techniques such as GC x GC-TOFMS. However, determining what dogs detect, and how that detection varies with environmental factors and the location of decomposition, will have great value in developing more successful

207. FED. R. EVID. 702.

208. P.H. Stefanuto, K.A. Perrault, R.M. Lloyed, B. Stuart, T. Rai, S.L. Forbes & J.F. Focant, *Exploring New Dimensions in Cadaveric Decomposition Odour Analysis*, 7(6) ANALYTICAL METHODS 2287 (2015) ("[b]ecause very little is known about how a positive canine alert is elicited, the identification of VOCs produced by decomposing remains (i.e. 'decomposition VOCs') is imperative to reach an improved understanding of potential analysis impacting canine olfaction.").

209. A further area needing study, particularly as to aerobic decomposition, involves how air movement affects the concentrations of chemicals will be available for a cadaver dog to detect. *See* Paul A. Moore, *Aerodynamics of Odor Plumes and Odor Plume Structures in Different Habitats*, *in* CANINE OLFACTION SCIENCE AND LAW: ADVANCES IN FORENSIC SCIENCE, MEDICINE, CONSERVATION, AND ENVIRONMENTAL REMEDIATION 87 (Tadeusz Jezierski, John Ensminger, & L.E. Papet eds. 2016).

210. Dogs have been shown to have the ability to distinguish between very similar chemicals. *See* Nathaniel J. Hall, Adriana Collada, David W. Smith & Clive D.L. Wynne, *Performance of Domestic Dogs on an Olfactory Discrimination of a Homologous Series of Alcohols*, 178 APPLIED ANIMAL BEHAV. SCI. 1, 1–6 (2016).

training aids.[211] Further, research should also include detection thresholds for individual odors involved within decomposition events, compare why different dogs will alert to different odors within a specified headspace, and how the training involved affects the outcome of this research. Of course, detection devices incorporating the results of research on the chemical profile of decomposition, such as artificial noses, may reduce the need for cadaver dogs, or the two could become corroborative of each other.

VI. CONCLUSIONS

The development of a chemical signature for human decomposition events is highly desirable. Research that was described by witnesses at the Anthony trial and research that has subsequently been published, is working towards that goal. As to why the chemicals listed in the decomposition database developed by Vass at the Oak Ridge Laboratory have not been made public, it is possible that many of the chemicals were found only in trace amounts and the researchers creating the database want to verify that other explanations for their presence have been thoroughly eliminated before exposing the work to criticism from peers. It may also be that the FBI feels that the conclusions of other researchers on what chemicals may be associated with human decomposition should be allowed to develop independently, providing more solid verification that those chemicals listed in the database are actually useful evidence of decomposition events.[212]

211. Katelynn A. Perrault, Katie D. Nizio & Shari L. Forbes, *A Comparison of One-Dimensional and Comprehensive Two-Dimensional Gas Chromatography for Decomposition Odour Profiling Using Inter-Year Replicate Field Trials*, 78(15) CHROMATOGRAPHIA 1057, 1069 (2015) ("developing a list of decomposition VOC biomarkers will be important for evaluating human-specific decomposition VOCs, for understanding cadaver dog olfaction and also for developing synthetic canine training aids."). Trainers of cadaver dogs cannot always train dogs on actual human remains. In a recent case, a county medical examiner broke the law by misappropriating human remains from an autopsy for use in cadaver dog training. The family sued when they learned of the use of the specimens from their relative's autopsy. Olejnik v. England, 147 F. Supp. 3d 763 (2015).

212. In a different scientific area that is currently developing, the possible capability of neuroimaging to detect deception, Jane Campbell Moriarty, *Visions of Deception: Neuroimages and the Search for Truth*, 42 AKRON L. REV. 739, 760 (2009), has recommended:

> an informal evidentiary moratorium on admission of this evidence unless and until the science has developed to a place where: (1) the scientists and their critics reach consensus that the results are truly valid, reliable, reproducible, accurate, and the error rate is within an acceptable margin of error; (2) the potential confounding problems related to sample size, group versus individual determinations, and the potential problems of correlation versus causation have been sorted out; and perhaps most importantly, (3)

The chemical signature of decomposition should include quantitative ranges of the chemicals that are found at different times after a victim's death,[213] in different environments,[214] and with victims differentiated by age, sex, diet, and other factors. The field is only beginning to involve multiple laboratories. Whether the compounds in this case were sufficient to establish a decomposition event in the trunk of the car will likely remain a matter of debate for a long time, but future research will undoubtedly improve hindsight.

It is regrettable a more thorough analysis of the application of evidentiary standards to the admission in a criminal trial of the chemical analysis introduced here was not made by an appellate court. Had there been a conviction on the more serious charges, this might have occurred. It is highly questionable, however, whether data should be filtered as drastically as occurred here with proprietary information and a single peer-reviewed study. The use of Vass's thirty-decomposition-chemical list may have been a tactical decision to move the playing field from a totally proprietary area into one that had some level of peer acceptance. Seeing the evidentiary threshold as resolved by the equipment used to reach the first list of fifty-one compounds makes cases like *Frye* and *Daubert* very easy thresholds to cross, and it must be doubted that this was the intent of the courts that attempted to establish criteria for the admission and evaluation of scientific evidence in criminal prosecutions and other contexts.

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there has been time for sufficient moral, ethical, and jurisprudential rumination about whether the legal system really wants this type of evidence.

Such a recommendation might be appropriate here.

213. Dekeirsschieter (2012), *supra* note 113 (identifying specific numbers of days for post-mortem periods).

214. *See* Sebastien Paczkowski & Stefan Schutz, *supra* note 84, at 917–35 (discussing micro-organisms involved in decomposition in different environments).

APPENDIX – REFERENCE LIST

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