

Environmental, Health, and Property Damage Issues Raised by Litigants Opposing Hydraulic Fracturing and Oil and Gas Production in Texas

Richard Bost, P.E., P.G. (Texas), Richard Bost Consulting and I2M Associates, LLC; Lori K. Magyar, Richard Bost Consulting; Michael D. Campbell, P.G., P.H., I2M Associates, LLC, Houston and Seattle

This paper has been selected for presentation and/or publication in the proceedings for the 2015 Gas Mexico Congress. The authors of this material have been cleared by all interested companies/employers/clients to authorize dmg: events (Canada) inc., the congress producer, to make this material available to the attendees of GMC15 and other relevant industry personnel.

ABSTRACT

Authors review environmental, health, and property damage issues raised by litigants opposing hydraulic fracturing and oil and gas production in Texas. The authors also review successful Daubert challenges that have barred speculative “expert” testimony in Texas. This paper provides an example of the kind of data presented by litigants as part of litigants’ risk assessment, identifies the flaws in the studies found by the court that barred similar testimony, and why experts’ opinions were barred.

KEY WORDS

Environmental damage, environmental exposure health risk assessments, oil and gas litigation, hydraulic fracturing damage claims, daubert challenges, barred expert testimony.

INTRODUCTION

Oil and gas exploration and production companies are facing increased litigation, in which opponents to oil and gas development have claimed environmental, natural resource, health, and property damages based on speculative “expert” opinions. Litigants are also suing parties in Texas courts for alleged damages associated with activities in Mexico. Some lower level district courts have barred speculative testimony. Other appeal courts have dismissed claims based on speculative testimony. In this paper we review the so-called “daubert” criteria which the U.S. Supreme Court established so lower courts can serve as gate-keepers allowing only expert testimony based on facts and scientific methods. Understanding these criteria will help defendants prepare successful “daubert” challenges to speculative and unfounded

claims and, where claims are truly legitimate, help claimants prepare sound evidence and expert opinions.

STATEMENT OF THEORY AND DEFINITIONS

In the matter of Daubert v Merrill Dow, 509 U.S. 579, 113 S. Ct. 2786, 125 L. Ed. 2d 469, 1993 U.S., the U.S. Supreme Court ruled that, to be admissible, expert scientific testimony that is derived from research done for the purpose of litigation must show that the conclusions were reached after following recognized scientific methods of research. (U.S. Supreme Court, 1993.)

When it comes to tort litigation relating to alleged damages associated with oil and gas operations, there is guidance for the courts determination of what is a fact and what is a scientific theory admissible in court.

Federal Rule 702 Testimony by Expert Witnesses (Rule 702) is now the standard for admitting expert scientific testimony.

- Under Rule 702, there are several factors to consider when determining whether testimony by an expert witness is admissible:
 1. Whether the theory is generally accepted in the scientific community;
 2. Whether the theory/method has been subjected to peer review and publication;
 3. Whether the potential or known rate of error is acceptable;
 4. Whether the theory/method has been tested or can be tested.

It is the court's responsibility to resolve disputes among the respected and credentialed scientists about matters within the scientists' expertise and to reject testimony if it is not obtained by the scientific method. Unfounded testimony is to be barred in order to avoid confusing the jury or record with misleading information.

If expert testimony is shown to be the result of research conducted for the purpose of litigation, the expert must show precisely how they reached their conclusions and point to an objective source to show they followed the scientific method as it is practiced by at least a recognized minority in their field. When experts cannot do this, the testimony is not admissible.

When experts have not conducted research independent of the litigation and the theories or methods followed for the research have not been published in scientific journals or reviewed by peers, and there has been ample time to do so, then the testimony is not admissible.

Under Rule 702, expert witnesses must also show that the evidence they offer is not "biased" and would assist the trier of fact in determining a factual issue and that their approach is sound. For example, in *Daubert v Merrill Dow*, the Plaintiffs' experts could not prove causation and say that the drug at issue doubled their risk of a birth defect, only that there was a statistical relationship between the drug and the birth defect. Statistical information presented as such could potentially be admissible, but not the "proof" of causation.

Litigants have recently claimed oil and gas related damages associated with the following issues:

- Compliance and Regulatory
- Economic
- Associated Activities: i.e: Mining of Sand/Gravel; Transportation
- Air Emissions
- Seismicity
- Surface and Ground Water Contamination
- Water Use
- Toxic Chemicals Management and Disposal
- Waste Management

Detailed discussion of each of these is beyond the limits of this presentation. Readers are directed to the references section for more detail. This paper presents a case study of expert testimony and air monitoring data used in recent litigation in the Dallas/Fort Worth area and which were barred

from use in litigation based on the rules of evidence, including Rule 702.

DATA AND OBSERVATIONS

The lead author was retained by counsel for a sued party to review data presented by Alisa Rich as her proof of environmental damages, health effects and property damage as part of litigation against local producers in multiple cases. (United States Court of Appeals of Texas; Fort Worth, 2013)

Alisa Rich presented data in each case from ambient air monitoring in residential areas "near" natural gas production facilities. She claimed the monitoring was performed using certified sterilized evacuated stainless steel 6-L Summa canisters with 24-hr flow regulators (certified mass-flow 24-hr meter). She has presented some of the data she has used in her expert reports in a recent publication (Rich, et al, 2014). Fifty ambient air sampling events occurred in residential areas in six counties in the Dallas/Fort Worth (DFW) Metroplex. Shale gas extraction and production is also occurring in the six counties in the Dallas/Fort Worth (DFW) Metroplex. The locations were identified by clients that requested monitoring.

Figure 1 identifies general location of sampling sites in DFW Metroplex. (Rich, et al, 2014)

RESULTS

Alisa Rich and her co-authors present the results of the sampling in a paper published in the *Journal of the Air & Waste Management Association*, 64(1):61-72, 201, in an article entitled "An exploratory study of air emissions associated with shale gas development and production in the Barnett Shale." Their results are represented in Table 1.

DISCUSSION

In 1993, the U.S. Supreme Court ruled in *Daubert* that the trial judge was the "gatekeeper" to prevent "junk science" from entering the courtroom. *Daubert* was the result of a lawsuit involving the drug Bendectin and its possible link to birth defects. At the trial, a series of "expert witnesses" testified to both sides of the issue. The Court, in its opinion partially ruled that "(1) the "general acceptance" test of *Frye v United States* (1923) 54 App DC 46, 293 F 1013, 34 ALR 145, was superseded by the Federal Rules of Evidence (FRE), and thus general acceptance is not a necessary precondition to the admissibility of scientific evidence under the FRE, given that (a) nothing in the text of Rule 702 of the FRE, governing expert testimony, establishes general acceptance as an absolute prerequisite to admissibility, and (b) there is no indication that Rule 702 or the FRE as a whole were intended to incorporate a general acceptance standard; (2) under the FRE, a federal trial judge must insure that any and all scientific testimony or evidence is not only relevant but reliable; and (3) in a federal case involving scientific evidence,

evidentiary reliability is based on scientific validity. The Court also provided the trial judge with some guidelines to use when deciding if scientific evidence should be admitted at trial. The Court suggested four factors to consider, they have become to be known as the “Daubert Factors”, they are; testing and validation, peer review, error rates, and lastly, the traditional Frye factor of general acceptance in the relevant scientific community.

Bost and Campbell, authors of this paper, have published a series of papers that can be used to guide experts in their work (Campbell et. al., 2004, Bost et. al., 2006) as have others (Fradella et. al. 2004).

The specific Case Study flaws in the alleged proof that oil and gas activities had affected the environment and the health and property values of the litigants follow:

1. Accepted practice for validation of the data were not followed. Tentatively identified compounds were often cited in the expert reports.
2. Peer reviews by the federal and state agencies, as well as the lead author and others found flaws in the expert report contentions and methods. (Ethridge, 2009, TDSHS 2010) Samples were collected on residential properties without controlling for wind direction; e.g., in Denton the wind direction was not from the direction of the “nearby” shale gas wells. Nor were upwind samples of the target source collected. Accordingly, accepted practice was ignored.
3. The data were alleged to match the “fingerprint” of shale gas; based on the detection of methane and benzene and other constituents. There are numerous urban and rural area sources of these constituents. Fingerprints of the natural gas produced in the area are available from the Texas Commission on Environmental Quality and the higher components of the gas were not detected.
4. Other alternative explanations and sources for the detections were not considered and eliminated. Other studies about sources of these constituents in the area and similar areas of the US were ignored.
5. Bias; statistical correlations were not run for alternative sources. Distances to sources were also not considered. Wind directions were not considered. Statistics correlations were run on internal relationships within the data rather than against known produced gas fingerprints.

CONCLUSION

The data as presented in Rich, et. al, 2014, are appropriately characterized in the title of the paper as “exploratory” and fail to meet the test of admissibility from a technical perspective for the reasons noted above. Plaintiffs and defendant experts can utilize the Daubert factors to guide them in developing valid, scientifically sound and defensible data and bases for their opinions. Doing so would further the safe development of the energy resources of Mexico and the U.S.

ACKNOWLEDGMENT

The Authors would like to acknowledge the contributions and information from the following:

- Texas Commission on Environmental Quality
- Texas Department of Health and Human Services
- Center for Disease Control and Prevention
- SEAK Expert Witness Directory
- American Bar Association
- I2M Associates, LLC., Houston and Seattle

REFERENCES

- Aguilera, K. 2014. *ALS Laboratory Report*
- American Bar Association. 2015. *District Court Limits Expert Testimony for Rendering Legal Conclusions*
- Armendariz, A. 2009. *Emissions from Natural Gas Production in the Barnett Shale Area and Opportunities for Cost-Effective Improvements.*
- Aiken, J. 2012. *Exploring Environmental Impacts Related to Frac Sand Mining and Processing – Minnesota Focus*, Barr Engineering Company, Minneapolis, Minnesota
- Bamberger, M., Oswald, R. 2012. *Impacts of Gas Drilling on Human and Animal Health*, New Solutions, **vol. 22(1) 51-77**
- Bankr. Court, ND Texas, 2014. Chapter 11 Cases: New Bankruptcy Opinion: In Re H&M Oil & Gas, LLC – Bankr. Court, ND Texas
- Booth, K.R and Tutrone, J.D. 2014, *DOT Compliance Responsibilities Increase for Rail Shipments of Crude Oil in the aftermath of Train Derailments.*
- Bost, R.C., Campbell, M.D., Campbell, M. David, Eckols, T.R., and Fono, Esq, A.L., 2006. *Flawed Geoscience in Forensic Environmental Investigations, Part II: How Daubert Affects the Scope and Basis for Expert Opinions.*
- Bost, R.C., Campbell, M.D., Campbell, M. David, Eckols, T.R., and Fono, Esq, A.L., 2006. *Flawed Geoscience in Forensic Environmental Investigations, Part III: How Daubert is a Surrogate for Ethical Questions Regarding Expert Opinions.*

- Bunch, A.G., Perry, C.S., Abraham, L., Wikoff, D.S., Tachovsky, J.A., Hixon, J.G., Urban, J.D., Harris, M.A., Haws, L.C. 2013. *Evaluation of impact of shale gas operations in the Barnett Shale region on volatile organic compounds in air and potential human health risks*. Science of the Total Environment.
- Calhoun, M.C. 2008. *Scientific Evidence in Court: Daubert or Frye, 15 Years Later*. Washington Legal Foundation **Vol.23 No. 37**
- Campbell, M.D., Bost, R.C., Campbell, M. David, 2004. *Flawed Geoscience in Forensic Environmental Investigations, Part I: The Effect of Daubert Challenges on Improving Investigations*.
- Center for Community and Business Research at the University of Texas at San Antonio's Institute for Economic Development. 2014, *Economic Impact of the Eagle Ford Shale*
- Center for Disease Control and Prevention. 2013. *NIOSH Update – New Interagency Collaboration to Focus on Impacts of Shale Gas Drilling*
- Center for Public Integrity. 2015. *Air Pollution Eagle Ford CH2MHill*. 2015. *U.S. Onshore Unconventional Exploration and Production Water Management Case Studies*. Prepared for the Energy Water Initiative
- Colborn, t. Kwiatkowski, C., Schultz, K., Bachran, M. 2011. Natural Gas Operations from a Public Health Perspective, Human and Ecological Risk Assessment: An International Journal, **17:5, 1039-1056**.
- Darrah, T.H., Vengosh, A., Jackson, R.B., Warner, N.R., and Poreda, R. J. 2014. *Noble gases identify the mechanisms of fugitive gas contamination in drinking-water wells overlying the Marcellus and Barnett Shales*. PNAS **vol 111 no. 39**
- Drug and Device Law Blogspot 2015, *Daubert – and a Mechanical Pencil – Doom the Testimony of “Clinical Engineering” Expert*
- Esswein, E.J., Snawder, J., King, B., Breitenstein, M., Alexander-Scott, M. 2014. *Preliminary Field Studies on Worker Exposure to Volatile Chemicals during Oil and Gas Extraction Flowback and Production Testing Operations* NIOSH Science Blog
- Ethridge, S. 2009. *Interoffice Memorandum: Health Effects Review of Ambient Air Monitoring Data Collected by Wolf Eagle Environmental Engineers and Consultants for DISH, TX*. Texas Commission on Environmental Quality
- Ewing, B.T., Watson, M.C., McInturff, R.N. 2014. *The Economic Impact of the Permian Basin's Oil and Gas Industry*, Permian Basin Petroleum Association, Midland Texas
- Faulk, R. O., No Date. *Perspectives on Daubert: Avoiding and Exploiting “Analytical Gaps” in Expert Testimony*.
- Fractracker Alliance. 2015. *Fracking's Most Wanted: Lifting the Veil on Oil and Gas Company Spills and Violations*, NRDC Issue Paper IP 15-01-A
- FracFreeDenton. 2014. *Videos, air sampling reveal Denton City's broken promises to monitor fracking pollution*.
- Fradella, H.F., O'Neill, L., and Fogarty, A. 2004. *The Impact of Daubert on Forensic Science*. Pepperdine Law Review Volume 31 | Issue 2 Article 1
- Freyman, M. 2014. *Hydraulic Fracturing & Water Stress: Water Demand by the Numbers*. A CERES Report
- Frolich, C., Brunt, M. 2013. *Two-year survey of earthquakes and injection/production wells in the Eagle Ford Shale, Texas, prior to the Mw 4.8 20 October 2011 earthquake*. Earth and Planetary Science Letters.
- Frohlich, C., W. Ellsworth, W. A. Brown, M. Brunt, J. Luetgert, T. MacDonald, and S. Walter. 2014. *The 17 May 2012 M4.8 earthquake near Timpson, East Texas: An event possibly triggered by fluid injection*, J. Geophys. Res. Solid Earth, 119 doi: 10.1002/2013JB010755.
- Gaughan, J.P. 2015. *Homeowners fail to prove well-water contamination caused by natural gas drilling*
- Hagstrom, E. L. 2012. *Hydraulic Fracturing: Risk and Regulation*, Oil & Gas Monitor
- Hagstrom, E. L. 2011. *Hydraulic Fracturing Litigation is on the Rise*. Hydraulic Fracturing Digest.
- Hornbach, M.J., DeShon, H.R., Ellsworth, W.L., Stump, B.W., Hayward, C., Frolich, C., Oldham, H.R., Olson, J.E., Magnani, M.B., Brokaw, C. and Luetgert, J. H. 2015. *Causal factors for seismicity near Azle, Texas*. Nature Communications.
- International Association of Defense Counsel Newsletter, 2014. *Hydraulic fracturing survives first jury trial test*
- Jaffe, K. 2012. *Shale gas drilling and public health: From CDC's National Center for Environmental Health and Agency for Toxic Substances and Disease Registry. First publication of full text email*
- Lustgarten, A. 2012. *Injection Wells: The Poison Beneath Us*. ProPublica
- Luxton, S.A, and Nes, W.B. 2012, *Daubert, Groundwater Contamination, and the Future of Fracking Litigation*, The Advocate Winter 2012, pp. 26 – 30
- Ly, M., 2015. *OSHA's New Target for SVEP – Oil and Gas Well Drilling Operations*
- Krupnick, A. 2013. *Managing the Ricks of Shale Gas Key finding and Further Research*.
- Maize, K. 2014, *Fracking Fissures: Will Politics Impede Production*.
- McFarland, J.B., and Miller, N.C. No Date. *Saltwater Disposal Well Leasing: High Waters Float all Boats*.
- McKay, L.K., Johnson, R.H., and Salita, L.A. 2011. *Science and the Reasonable Development of Marcellus Shale Natural Gas Resources in Pennsylvania and New York*, Energy Law Journal, **Vol 32:125**

- Nicholson, Barclay R. 2014. *Analysis of Litigation Involving Shale & Hydraulic Fracturing*, Norton Rose Fulbright
- Nicot, J.P. and Scanlon, B.R. 2012. *Water Use for Shale-Gas Production in Texas*. Environmental Science & Technology **46**, 3580 – 3586
- Norwood, E.R. 2002. *Expert Witnesses in Oil and Gas Litigation: Robinson/Daubert Challenges*, Cotton, Bledsoe, Tighe & Dawson P.C.
- Olaguer, E. 2012. *The potential near-source ozone impacts of upstream oil and gas industry emissions*. Journal of the Air & Waste Management Association
- Pantsios, A. 2015. *Citizens Can Sue Fracking Companies for Earthquake Damage, Says Oklahoma Supreme Court*. Ecowatch.com
- Phillips, S. 2012. *CDC Wants to Track Fracking Chemicals*
- PHMSA, 2015. *Emergency Response Notifications for Shipments of Petroleum Crude Oil by Well*
- Power, T.M, Power, D.S. 2013. *The Economic Benefits and Costs of Frac-Sand Mining in West Central Wisconsin*
- Rich, A., Grover, J.P., and Sattler, M.L. 2014. *An exploratory study of air emissions associated with shale gas development and production in the Barnett Shale*, Journal of the Air & Waste Management Association, 64:1, 61 – 72, DOI: 10.1080/10962247.2013.832713
- Richardson, N., Gottlieb, M., Krupnick, A. and Wiseman, H. 2013. *The State of State Shale Gas Regulation*. RFF
- Ridlington, E., Rumlper, J., 2013 *Fracking by the Numbers*
- Schaeffer, B.S., Ogulnick, S., Schaeffer, S.A. 2008. *Challenges to the Admissibility of Expert Financial Testimony: 2005 - 2008*
- SEAK Expert Witness Directory. No Date. *Admissibility of Expert Witness Testimony: The 10 most important cases citing Daubert*
- SEAK Expert Witness Directory. No Date. *Surviving a Daubert Motion: 18 Tips for Your Expert Witness*
- Shale Play Water Management. 2015. *States Consider Changes to Disposal Well Regulations*.
- Shaw, J. 2014. *Anti-fracking activist sticks by industry "expert" who was proven to be a fraud*
- Shonkoff, S. B., Hays, J., Finkel, M. L. 2014. *Environmental public health dimensions of shale and tight gas development*. Environ Health Perspect **122:787 - 795**
- Smith, P. and Phillips, T. 2014. *Dodging Daubert: Expert Opinions in Property Value Diminution*. Alvarez & Marsal
- Sumi, L. 2012. *Breaking All the Rules The Crisis in Oil & Gas Regulatory Enforcement*, Earthworks
- Taylor, T.R. and Luxton, S.A. 2013. *Fracking Litigation and Daubert Challenges, Defending Against and Asserting Challenges to Expert Witness Evidence*. Strafford Webinar.
- Texas Commission on Environmental Quality. 2011 – 2014. *Annual Enforcement Report*, Enforcement Division, Office of Compliance and Enforcement
- Texas Commission on Environmental Quality. No Date. *Automated Gas Chromatographs (AutoGCs) Barnett Shale Monitoring Network*. http://www.tceq.state.tx.us/airquality/monops/agg/agc_barnett.html
- Texas Department of State Health Services. 2010. *DISH, Texas Exposure Investigation, DISH, Denton County, Texas*
- Texas Department of State Health Services. 2014. *Updated Summary Report Occurrence of Cancer In Zip Codes 75022 & 75028 Flower Mound, Denton County, Texas Time Period: 2002–2011*
- Texas Railroad Commission. 2012 – 2015. *Report on Oil and Gas Field Operations' Violations and Enforcement*
- Thompson, Esq. R. 2015. *Daubert Decisions Not Just for District Courts Anymore*. The National Law Review
- Thurman, C.F. and Williams, O.K. 2014, *Serious Procedural Barriers to Fracking Litigation*. American Bar Association
- United States Bureau of Land Management. 2015. *43 CFR Part 3160 Oil and Gas; Hydraulic Fracturing on Federal and Indian Lands; Final Rule*. Federal Register **Vol. 80. No. 58**
- United States Court of Appeals of Texas; Fort Worth. 2013. *Re: Steven and Shyla Lipsky and Alisa Rich, Realtors* No. 02–12–00348–CV
- United States Environmental Protection Agency. 2012. *Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources*.
- United States Environmental Protection Agency. 2014. *Minimizing and Managing Potential Impacts of Injection-Induced Seismicity from Class II Disposal Wells: Practical Approaches*. Underground Injection Control National Technical Workgroup
- United States General Accounting Office. 1989. *Drinking Water: Safeguards Are Not Preventing Contamination from Injected Oil and Wastes* **GAO/RCED – 89-97**
- United States Supreme Court, 1993. *Daubert et ux., individually and as guardians and litem for Daubert, et.al.V. Merrell Dow Pharmaceuticals, Inc.*
- Valentine, K. 2014. *Companies are Fracking with Harmful Chemicals through Regulatory Loophole*. ThinkProgress.com
- Webb, R. 2015. *Oil and gas producers likely to face tougher regulation in 2015*. KBH Energy Center Blog

TABLE 1 – Excerpt From An exploratory study of air emissions associated with shale gas development and production in the Barnett Shale. (Rich, et al, 2014)

Table 2. Summary statistics

CAS No.	Chemical	Min (ppb _v)	Max (ppb _v)	Median (ppb _v)	Mean (ppb _v)	SD	No. of ND
74828	Methane (ppm _v)	1.9	457	2.7	11.99	63.58	1
71432	Benzene	0.6	592	0.89	18.53	83.75	11
67663	Chloroform	0.2	2.58	0.3	0.45	0.46	46
74873	Chloromethane/Methyl chloride	0.25	5.33	0.6	0.68	0.71	17
75718	Dichlorodifluoromethane (F12)	0.25	1.13	0.45	0.48	0.17	9
76142	Dichlorotetrafluoroethane (F114)	0.2	1	0.3	0.36	0.17	47
107062	1,2-Dichloroethane (EDC)	0.2	1	0.3	0.34	0.15	49
75092	Dichloromethane/Methylene chloride	0.2	1	0.3	0.34	0.15	49
100414	Ethylbenzene	0.2	113	0.53	4.42	16.03	23
87683	Hexachlorobutadiene	0.25	2.6	0.7	0.73	0.46	42
100425	Styrene	0.2	43.4	0.37	1.91	6.22	26
79345	1,1,2,2-Tetrachloroethane	0.2	2.06	0.3	0.37	0.28	49
127184	Tetrachloroethene (PCE)	0.2	2.43	0.3	0.33	0.39	47
108883	Toluene/Methylbenzene	0.34	276	2.55	19.45	48.77	3
108678	1,3,5-Trimethylbenzene	0.2	9.95	0.59	1.43	2.12	25
95636	1,2,4-Trimethylbenzene	0.2	60.4	0.4	3.45	10.79	27
120821	1,2,4-Trichlorobenzene	0.28	13.5	0.67	1.12	1.93	10
79016	Trichloroethene (TCE)	0.2	60.9	0.3	1.58	8.48	47
75694	Trichlorofluoromethane (F11)	0.2	1	0.3	0.34	0.15	45
1330207	<i>m</i> - and <i>p</i> -Xylene	0.25	221	1.68	15.69	43.1	7
95476	<i>o</i> -Xylene	0.2	39.4	0.85	3.19	6.7	15
75150	Carbon disulfide	0.7	103	4	11.75	20.5	22
463581	Carbonyl sulfide	0.3	36.7	1.41	4.22	7.1	40
624920	Dimethyl disulfide	0.3	200	1.93	15	31.56	29
20333395	Methyl ethyl disulphide	0.3	145	1.78	11.18	24.27	31
611143	Ethylmethylbenzene	0.3	42.8	1.4	3.15	6.74	47
2179604	Methyl propyl disulfide	0.3	41.6	1.4	2.59	5.71	49
110816	Diethyl disulfide	0.3	32.7	1.5	3.15	5.92	43
53966362	Ethyl, methylethyl disulfide	0.3	46.7	1.4	3.68	8.87	46
3658808	Dimethyl trisulfide	1.2	46.3	1.52	8.02	14.86	37
30453317	Ethyl <i>n</i> -propyl disulfide	0.3	25.2	1.4	2.25	3.48	48
95636	Trimethylbenzene	0.3	366	1.4	15.18	58.39	46
11020214	Undecane	0.3	72	1.4	3.05	9.88	49
2082613	1-Methyl propenylbenzene	0.3	51	1.4	2.63	6.96	49
112403	Dodecane	0.3	29	1.4	2.19	3.91	49
767599	1-methyl-1H Indene	0.3	79	1.4	3.19	10.86	49
768490	2-Methyl propenyl benzene	0.3	95.9	1.4	3.53	13.22	49
103651	Propylbenzene	0.3	23.5	1.4	2.08	3.16	49
25340174	Diethylbenzene	0.3	93.4	1.4	4.14	13.56	48
19876	Methyl-methylethylbenzene/methylcumene	0.3	84.7	1.4	3.31	11.65	48
110189	Tetramethylbenzene	0.3	36.4	1.4	2.76	5.69	48
91203	Napthalene/Trimethylbicyclo[2.2.1]heptane	0.3	30.3	1.4	2.5	4.27	47
109068	Methylpyridine	0.3	210	1.4	5.81	29.18	49
108485	Diethyl pyridine/Aldrich	0.3	48.2	1.4	2.56	6.43	49
100710	Ethylpyridine	0.3	69.4	1.4	3	9.52	49
78784	2-Methylbutane	0.3	3620	1.4	88.04	507.51	44
109660	Pentane	0.3	198	1.4	7.73	28.59	45
108087	2,4-Dimethylpentane	0.3	50	1.4	2.61	6.82	49
963772	Methyl cyclopentane	0.3	22	1.4	2.4	3.75	48
561764	2-Methylhexane	0.3	35.3	1.4	2.71	5.44	48
565693	2,3-Dimethylpentane	0.3	98	1.4	3.57	13.51	48
589344	3-Methylhexane	0.3	2300	1.4	49.02	321.63	46

(Continued)

TABLE 1 – Continued

Table 2. (Cont.)

CAS No.	Chemical	Min (ppb _v)	Max (ppb _v)	Median (ppb _v)	Mean (ppb _v)	SD	No. of ND
108872	Methylcyclohexane	0.3	38	1.4	2.42	5.15	48
540841	2,2,4-Trimethylpentane	0.3	17	1.4	1.95	2.29	49
	C3 Hydrocarbon	0.3	51.4	1.4	5.57	9.7	42
	C4 Hydrocarbon	0.3	137	1.4	6.6	21.61	44
	C5 Hydrocarbon	0.3	6780	1.65	145.24	947.97	28
	C6 Hydrocarbon	0.3	294	1.6	18.06	51.83	30
	C7 Hydrocarbon	0.3	2390	1.5	56.64	333.96	38
	C8 Hydrocarbon	0.3	1420	1.5	39.44	199.78	36
	C9 Hydrocarbon	0.3	761	1.41	19.78	106.43	42
	C10 Hydrocarbon	0.3	191	1.5	11.75	30.7	37
	C11 Hydrocarbon	0.3	53.6	1.4	3.92	9.51	46
	C12 Hydrocarbon	0.3	395	5	23.81	59.1	22
	C13 Hydrocarbon	0.3	231	1.57	10.88	35.03	40
76641	Acetone	0.3	20.7	1.4	2.04	2.81	49
74986	Propane (ppm _v)	1	62.9	1.4	2.97	8.65	48
106978	Butane (ppm _v)	1	69	1.4	2.95	9.45	48
74840	Ethane (ppm _v)	1	34.6	1.4	2.24	4.66	49
75285	Isobutane	0.3	34	1.5	3.95	6.38	38
79925	Camphene	0.3	5.2	1.4	1.65	0.81	49
592574	Cyclohexadiene	0.3	7.1	1.4	1.76	1.1	49
103651	Propynylbenzene	0.3	7.2	1.4	1.74	1.13	49
226666	Diethyl trisulfide	0.3	8.23	1.41	2.14	1.62	43
513359	Methylbutane	0.3	16	1.4	1.93	2.16	49
2511957	Dimethylcyclopropane	0.3	29	1.4	2.19	3.91	49
75832	Dimethylbutane	0.3	15	1.4	1.91	2.03	49
107835	Methylpentane/Isohexane	0.3	199	1.4	6.1	27.79	48
110543	Hexane	0.3	35	1.4	2.46	4.81	48
138863	Limonene	0.3	12.9	1.4	2.14	2.15	47
	Dimethylpentatnone	0.3	42.8	1.4	2.47	5.82	49
	Bromohexene	0.3	5.2	1.4	1.69	0.84	49
3728550	Ethylmethylcyclohexane	0.3	6.1	1.4	1.82	1.15	48
4316658	Trimethylhexene	0.3	11.9	1.4	1.85	1.64	49
1072168	Dimethyloctane	0.3	20.4	1.4	2.02	2.74	49
7785708	1- <i>R</i> -alpha-pinene/2-Pinene/ 2.6.6Trimethylbicyclo[3.3.1]hept-2-ene	0.3	29	1.4	2.18	3.91	49
496117	Indane	0.3	15.2	1.4	1.9	2.06	49
590738	2,2,-Dimethylhexane	0.3	168	1.4	4.97	23.3	49
251412	Thieno[3,2] thiopene	0.3	56.5	1.5	5.18	10.7	43
78853	Methacrolein	0.3	1710	1.4	35.74	239.18	49
106467	1,4-Dichlorobenzene	0.2	4.43	0.3	0.55	0.66	45
591764	Methylhexane	0.3	25	1.4	2.11	3.66	46
75694	Trichlorofluoromethane	0.3	5.2	1.4	1.64	0.79	49
75456	Difluorochloromethane	0.3	45	1.4	2.51	6.12	48
137631	Tetramethylcyclopentane	0.3	9.24	1.4	1.79	1.33	49
4926787	Ethylmethylcyclohexane	0.3	5.68	1.4	1.78	1.04	48
6069983	Methylmethylethylcyclohexane	0.3	6.17	1.4	1.73	1.01	49
543599	Chloropentane	0.3	5.2	1.4	1.65	0.8	49
592574	1,3-Cyclohexadiene	0.3	5.8	1.4	1.73	0.98	49
60779240	Methyl <i>n</i> -butyl disulfide	0.3	15.5	1.4	1.92	2.1	49
72437640	Propyl <i>n</i> -butyl disulfide	0.3	14.6	1.4	1.9	1.98	49
629196	Dipropyl disulfide	0.3	23.1	1.4	2.07	3.11	49

FIGURE 1. Excerpt From An exploratory study of air emissions associated with shale gas development and production in the Barnett Shale. (Rich, et al, 2014) showing Sample Locations in the Dallas/Fort Worth Metroplex

