

High-Level Petroleum Hydrocarbon Vapor Exposures Induce Toxic Encephalopathy

This case study demonstrates how causation can be demonstrated by weight of evidence (WOE) and how objective investigation of contributing factors can play a pivotal role in formulating an expert opinion to reasonable toxicological certainty.

A process engineer worked for seven years at a petroleum refinery. After several years of near-continuous exposure to benzene, hydrofluoric acid, gasoline and other volatile petroleum hydrocarbon vapors, he began experiencing nocturnal headaches, difficulty sleeping, situational stress and anxiety. Although he initially attributed his symptoms to job stress, he began experiencing extreme fatigue, diminished energy, lack of concentration, body aches, chills, mood swings, confusion, increased somnolence and depression.

His physician initially attributed the symptoms to thyroid disease, but this diagnosis was later ruled out. He transferred to an indoor office in the hope of improvement, but instead, his symptoms grew worse. He began experiencing intermittent jerking movements and involuntary muscle twitches. Eventually, he could no longer perform his job duties. An objective brain scan resulted in a diagnosis of occupational, exposure-based toxic encephalopathy consistent with exposure to hydrocarbons over a period of years. Soon the symptoms increased to such an extent that he became completely disabled.



Toxic encephalopathy can be caused by repeated exposure to refinery hydrocarbon vapors.^[a]

Causation Demonstrated by Weight-of-Evidence

Plaintiff subsequently filed a lawsuit against the company who promptly denied any wrongdoing. The company attempted to prove in court that plaintiff's injury could not have been caused by the work environment or by negligence. Dr. Sawyer was retained to determine whether or not the exposures were responsible. However, such a determination required compelling, demonstrable weight-of-evidence (WOE) meeting generally-accepted causation criteria which unequivocally demonstrated and isolated the factors contributing to the plaintiff's condition.

Upon reviewing the available historical documentation, Dr. Sawyer found that the refinery had been cited for numerous hazardous violations over the years which put its workers, including the plaintiff, at risk for toxic exposures. He further discovered that proper personal protective equipment (PPE) had generally not been provided. Dr. Sawyer compiled an exhaustive set of industrial hygiene data (all of which had been created by the company itself) which clearly demonstrated a historical pattern of violations and repeated overexposures.

Toxic encephalopathy is a type of structural brain damage or brain dysfunction secondary to an exposure from a chemical causing severe injury and destruction of neurons. The criteria for toxic encephalopathy induced by long-term occupational exposure to organic solvents is specific. A toxicological diagnosis of solvent-induced toxic encephalopathy requires that the following criteria be met:

- Long or intense exposure to solvents approaching or exceeding NIOSH recommended exposure limits (RELs)
- Relevant symptoms such as increased fatigue, memory impairment, difficulties in concentration and personality changes such as passivity
- The presence of pathological findings in terms of an objective measurement
- A relation in time between exposure and the development of symptoms and signs
- No other obvious cause of the disease
- Effects on the central nervous system which persist even after exposure had ceased

To evaluate these criteria, Dr. Sawyer produced a toxicological report which detailed the following evidence supported by numerous peer-reviewed studies:

- **Exposure:** Plaintiff worked for years in areas of heavy vapor concentrations (Fluid Catalytic Cracking, Hydroalkylation, etc) at levels near and sometimes in excess of NIOSH recommended exposure limits (RELs). His family frequently noted that he came home smelling like gasoline and other chemicals.
- **Onset of Symptoms:** Plaintiff experienced significant neurological symptoms beyond work hours including nocturnal headaches, difficulty sleeping, stress and anxiety, extreme fatigue, diminished energy, lack of concentration, body aches, chills, mood swings, confusion, increased somnolence, depression, intermittent jerking movements and muscular twitching. These symptoms were all reasonably attributable to excessive hydrocarbon exposures. Plaintiff was ultimately diagnosed by a physician with toxic encephalopathy.
- **Sequence of Events:** Symptom onset was consistent with plaintiff's employment history and with numerous peer-reviewed studies and generally-accepted diagnostic criteria (published in referenced studies) and as defined by the World Health Organization¹ and NIOSH.²
- **Lack of Alternate Causation:** Plaintiff was a lifetime non-smoker with no history of substance abuse. His medical records revealed no reasonable alternative causes. However, substantial evidence existed for over-exposure to neurotoxic hydrocarbons at the refinery over a period of years.
- **History of Safety Violations:** The refinery had been cited for numerous violations that placed its workers (including plaintiff) at risk for toxic exposures. Records also showed that the company was significantly under-reporting its leak rates and failing to properly monitor its units for leaks.
- **Inadequate Medical Monitoring:** Although the company claimed that industrial hygiene personnel were monitoring hundreds of workers for toxic exposures, there were only three such individuals in the facility, none of whom were certified industrial hygienists.
- **Inadequate Medical Testing:** Only a single urine phenol sample (which was deemed unreliable) was collected from plaintiff during seven years of exposure in a known hazardous atmosphere. This single sample represented less than 0.057% (1 out of 1,750 days) of his total exposure history. The physician also opined that plaintiff's symptoms became worse at his office job as he had actually moved closer to sources of vapor and his exposures now occurred in a confined space.
- **Documented Instances of Benzene Emissions:** Oily water and sewer waste had infiltrated the storm sewer system and waste was being vented into the atmosphere at a rate equal to or exceeding 35 times the permissible exposure limit under OSHA regulations. The company was also aware of the leakage of hazardous chemicals under the plant and had been cited for numerous benzene-related safety violations.
- **OSHA Non-Compliance (Benzene):** The company's inspection record showed numerous instances of non-compliance with benzene emission levels permitted by OSHA, particularly in areas in which the plaintiff worked. There was also considerable evidence in the form of historical documentation that volatile hydrocarbons from various leaks were measured near valves and fittings in excess of 500 to 1000 PPM, far in excess of any legally-permissible vapor levels.
- **Broad Range of Contaminants:** Plaintiff was exposed to benzene, toluene, ethylbenzene, xylenes (a mixture known as "BTEX"), gasoline, jet fuel and a wide range of aliphatic hydrocarbons consistent with ongoing refinery operations. These hydrocarbons have been confirmed in multiple human epidemiological studies to induce toxic encephalopathy among workers chronically exposed to levels near the OSHA PEL.
- **Excessive TPH (Total Petroleum Hydrocarbons):** The limited industrial hygiene surveys conducted at the refinery revealed numerous violations of the OSHA PEL for benzene. The industrial hygiene data revealed measurements of benzene and TPH within the refinery at a ratio of 1 part benzene per 97.1 ± 15 parts TPH. Applying this ratio to out-of-compliance benzene readings within various refinery units revealed TPH levels in the 97.1 PPM to 46,802 PPM range. TPH mixtures composed of BTEX and aliphatic hydrocarbons have been demonstrated in human epidemiological studies to induce toxic encephalopathy within that range of exposure.

To visualize this final point, Dr. Sawyer produced a compelling demonstrative for the judge and jury which characterized benzene air samples taken at the refinery during plaintiff's period of employment. This demonstrative (below) showed that out of 26 air samples collected over a period of several days, 21 of them failed to meet OSHA quality standards.

AIR SAMPLE RUN LOG					
Plant-Wide Shutdown Activities Amount of Air Injected: 1.0 ml			OSHA Permissible Exposure Limit (PEL): 1.0 ppm OSHA Action Level (AL): 0.5 ppm		
DATE	SAMPLE ID	SAMPLE LOCATION	CONC (ppm)	P/F	
2/17	AS02007	Downwind 25' SW of LOC-10	34.1	FAIL	
2/17	AS02009	Operations office, 30' W of LOC-9	3.73	FAIL	
2/17	AS02020	Shutdown trailer No 1	0.54	FAIL	
2/17	AS08006	S of LOC-10	3.28	FAIL	
2/17	AS08008	S of LOC-13	0.24	Pass	
2/17	AS08009	S of LOC-9 & LOC-10	25.6	FAIL	
2/17	AS08020	SW of LOC-12	1.42	FAIL	
2/17	AS08022	10' W of LOC-11	0.26	Pass	
2/18	AS02022	5' NW of LOC-5 downwind from contamination	33.4	FAIL	
2/18	AS02022	Downwind 25' NW of LOC-19	VOID	-	
2/18	AS02023	Downwind 45' NW of LOC-19	2.44	FAIL	
2/18	AS02027	Operations office	0.61	FAIL	
2/18	AS02028	Shutdown trailer No 28	0.21	Pass	
2/18	AS05026	Below 1791 & 1792 sewer hole	89.8	FAIL	
2/18	AS08022	Inside shutdown trailer	BDL	Pass	
2/18	AS08023	10' S of LOC-9 & LOC-10	0.33	Pass	
2/18	AS08025	15' NW of LOC-67	11.5	FAIL	
2/18	AS08026	15' NW of LOC-66	3.75	FAIL	
2/18	AS08027	Outside of barricade near LOC-6	2.06	FAIL	
2/19	AS02029	10' n of LOC-35	8.08	FAIL	
2/19	AS02020	5' NW of LOC-54	1.81	FAIL	
2/19	AS02022	5' NW of LOC-63	7.43	FAIL	
2/19	AS02022	15' SE of LOC-3 @ drain access	41.9	FAIL	
2/19	AS02023	H-1 in 1391	3.9	FAIL	
2/19	AS02024	30' W of LOC-18	4.19	FAIL	
2/19	AS02025	Draining at 308-LOC-62	0.76	FAIL	
2/19	AS02029	5' S of LOC-9 steaming	4.71	FAIL	
				Pass:	5
				Fail:	21
				Average Concentration (ppm):	11.4

Courtroom demonstrative showing preponderance of contaminated air samples.^(b)

This demonstrative showed not only the degree of fugitive vapors present in the environment at the time samples were taken, but also portrayed the scope of violations characterizing the company's inspection record. This damaging piece of evidence clearly demonstrated that the average airborne concentrations of petroleum hydrocarbon vapors were far above the Permissible Exposure Limit (PEL) and that such violations were a frequent and common occurrence at this particular refinery. Dr. Sawyer further demonstrated that the company was out of compliance with NIOSH-recommended exposure limits in numerous respects and that such events were consistent over a period of years.

Summary

Dr. Sawyer provided both forensic evidence and causation weight-of-evidence in light of the available facts and scientific evidence with respect to the induction of toxic encephalopathy. Extrapolation of the benzene air levels to provide total petroleum hydrocarbon air levels revealed that exposures within the range consistent with the induction of toxic encephalopathy occurred with benzene measured at levels far in excess of the OSHA PEL.

Outcome

Dr. Sawyer was able to demonstrate to *reasonable toxicological certainty* that plaintiff's exposure, symptoms and history were fully consistent with the diagnosis of toxic encephalopathy resulting from excessive exposures to hydrocarbon leaks, spills and emissions. The court denied repeated attempts by defendant to challenge and exclude Dr. Sawyer's report and testimony. The company ultimately settled the case ahead of a likely verdict in favor of plaintiff.

(Disclaimer: Toxicology case studies are impartial and objective summaries of toxicological matters in which TCAS was retained for the purpose of assessing health-based factors which, in some cases, led to a determination of causation. No names or identifying information have been provided due to privacy and legal considerations. In the above matter, Dr. Sawyer was retained by plaintiff.)

Notes and References

1. WHO, Nordic Council of Ministers. "Organic solvents and the central nervous system," EH5. Copenhagen, Denmark, 1985.
2. NIOSH, "Current Intelligence Bulletin 48, Organic Solvent Neurotoxicity," March 31, 1987, US Department of Health and Human Services. Ohio.

Images

- a. Adapted from photo by [Carlos Koblischek](#)
- b. TCAS report demonstrative (redacted), graphical image © Copyright 2017 TCAS, LLC.

A Message from Dr. William R. Sawyer Chief Toxicologist, TCAS, LLC



"A toxicological finding must be based on credible science and compelling evidence. Numerous peer-reviewed studies have defined the exposure levels and durations needed to support a finding of toxic encephalopathy."

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