

955 S.W.2d 257 (1997)**Kenneth McDANIEL, Plaintiff-Appellee,****v.****CSX TRANSPORTATION, INC., Defendant-Appellant.****Supreme Court of Tennessee, at Nashville.**

September 29, 1997.

Rehearing Denied December 8, 1997.

258 *258 Wayne L. Robbins, Jr., Gareth S. Aden, Gullett, Sanford, Robinson & Martin, PLLC, Nashville, Edward H. Stopher, Boehl, Stopher & Graves, Louisville, KY, for Defendant-Appellant.

Van Kirk McCombs, II, James H. Wettermark, Burge & Wettermark, P.C., Birmingham, AL, for Plaintiff-Appellee.

OPINION

ANDERSON, Chief Justice.

We granted this interlocutory appeal to clarify the standards for the admissibility of scientific evidence under Tennessee Rules of Evidence 702 and 703.

The trial court, after a Tenn. R. Evid. 104 pretrial evidentiary hearing, admitted into evidence the testimony of plaintiffs' experts who relied on epidemiological studies to prove that exposure to organic solvents caused a form of brain damage known as toxic encephalopathy. The trial court found that this scientific evidence would substantially assist the trier of fact and was reliable and trustworthy.

The Court of Appeals denied an interlocutory appeal. We, however, granted the interlocutory appeal and conclude that Tennessee Rules of Evidence 702 and 703 impose a duty upon trial courts to determine whether scientific evidence will substantially aid the trier of fact and whether the underlying facts and data relied on by the expert witness indicate a lack of trustworthiness. The trial court must further determine whether the reasoning or methodology underlying the scientific evidence is sufficiently valid and reliable, and whether it can properly be applied to the facts at issue.

In making this determination, the trial court should focus on the principles and methodology underlying the science, and not on the conclusions of experts. The trial court is not required to determine that the principles and methodology employed are generally accepted by the scientific community. The court needs only to determine that the principles and methodology are scientifically valid and reliable.

When these standards are applied in this case, the scientific evidence proffered by the plaintiffs should be admitted. Accordingly, we conclude that the trial court did not abuse its discretion in denying the defendant's motion in limine which sought to exclude the plaintiffs' expert testimony.

BACKGROUND

259 This case involves eighty-four (84) cases filed pursuant to the Federal Employers Liability Act, 45 U.S.C. § 51, *et seq.*, by employees of the defendant **CSX** Transportation, Inc. ("CSXT"), a railroad operator, which were consolidated for motions and case management in the Davidson County Circuit Court. Each plaintiff alleges that he has suffered brain damage due to chronic exposure to four (4) particular organic solvents^[1] *259 while working in the CSXT mechanical shops in Nashville, Tennessee.

The plaintiffs intend to rely upon occupational physicians to show that long-term, low dosage exposure to the solvents has caused a form of brain damage known as toxic encephalopathy, which is marked by diminished short-term memory, sleeplessness, depression and anxiety. The plaintiffs' experts rely upon epidemiological studies,^[2] which they contend established the causation between long term exposure to solvents and damage to the central nervous system.

CSXT sought to exclude the plaintiffs' experts on the basis that their testimony was without sufficient scientific support. CSXT contended that the epidemiological studies relied on by the plaintiffs did not consistently establish a causal connection with a relative risk or odds ratio that shows a statistically significant degree of reliability.^[3] It concluded, therefore, that the proffered expert testimony on the issue would not "substantially assist" the trier of fact, and that the facts and data underlying the testimony shows a "lack of trustworthiness."

At a pretrial Tenn. R. Evid. 104 evidentiary hearing, several expert witnesses for the plaintiff and the defendant offered their opinions concerning the effect of long-term exposure to low doses of the organic solvents involved in this litigation. The proof indicated that the solvents belong to a family of organic solvents known as chlorinated hydrocarbons, while mineral spirits are generally distilled from petroleum products. The industrial utility of the solvents lies in their ability to dissolve grease.

The experts agreed that there is no objective diagnostic tool, (such as an MRI, CT Scan, or X-Ray), that will support a diagnosis of toxic encephalopathy, and that no biological mechanism has been identified that demonstrates how exposure to the solvents causes the damage. Moreover, while the experts agreed that acute exposure to high concentrations of the solvents can create dizziness, disorientation, and even unconsciousness, the allegations in this case involve exposure below the level necessary to render a person unconscious.

One of the plaintiffs' experts, Dr. Edward Baker, a physician specializing in occupational medicine with two masters degrees, one in public health and another in epidemiology, testified that he has authored twenty-six articles and four textbook chapters on the subject of the effects of exposure to solvents. He began studying the effects of solvent exposure on the central nervous system while on the faculty of Harvard University's School of Public Health. He has summarized
260 epidemiological studies conducted since 1985 and *260 has concluded that "these cross sectional studies, viewed in the aggregate, support the view that chronic solvent exposure causes impairment of neurobehavioral function." Baker, "A Review of Recent Research on Health Effects of Human Occupational Exposure to Organic Solvents," *Journal of Occupational Medicine*, Vol. 36, No. 10 (Oct. 1994).^[4] Baker testified that dose/response and degree of exposure were critical to the causation inquiry.

Another plaintiffs' expert, Dr. Douglas Linz, also a physician specializing in occupational medicine, has authored four articles on the effects of exposure to solvents and has diagnosed patients with chronic encephalopathy. Like Baker, he has performed and reviewed the epidemiological studies on the subject and has concluded that "chronic low dose exposure to solvents can cause chronic encephalopathy." Dr. Howard Frumkin, a physician with a doctorate in public health, has evaluated patients for solvent exposure, and has researched and written on the effects of exposure on the central nervous system. He testified that a sufficient degree of exposure over a sufficient amount of time can cause toxic encephalopathy, and that the diagnosis of chronic encephalopathy from low dose exposure to solvents is generally accepted throughout the United States and the world.^[5]

In contrast, Dr. Philip Edelman testified on behalf of the defendant that although dose response is critical to any toxicology study, "most" in the medical community of toxicologists did not accept the causal connection between low dose exposure to solvents and encephalopathy. Edelman, a physician who is board certified in toxicology and occupational/environmental medicine, criticized the epidemiological studies that the plaintiffs' experts relied upon for lacking a good dose/response relationship and for failing to control for confounding factors such as age, intelligence, and the use of alcohol. Likewise, Dr. Joseph McLaughlin, a Ph.D. in epidemiology, testified that the epidemiological studies on the relation between exposure to solvents and toxic encephalopathy failed to account for significant confounding factors. Finally, Dr. Robert James, a Ph.D. in pharmacology, testified that he reviewed forty-five cross sectional studies and determined that 84 percent supported the hypothesis and 16 percent did not. He criticized the "positive" studies, however, for failing to account for the factors of age, intelligence, experience, and alcohol consumption. In James's opinion, the diagnosis of toxic encephalopathy from

exposure to solvents was not generally accepted in the medical community.

After considering the testimony of the experts and analyzing the pertinent studies, the trial court concluded that the proposed evidence was "grounded in scientific theory," was "generally accepted in the occupational health community," and was trustworthy and reliable. Although denying the defendant's motion to exclude the expert testimony, the trial court recognized the need to develop a uniform and consistent body of law and granted the defendant's motion for an interlocutory appeal pursuant to Tenn. R.App. P. 9. Although the Court of Appeals denied the interlocutory appeal, we granted the appeal to clarify the standards for determining the admissibility of scientific evidence in this jurisdiction. We now affirm the trial court.

SCIENTIFIC LITERATURE

261 We begin our analysis by reviewing the relevant material that was submitted to the trial court and discussed by several of the experts during the evidentiary hearing. In the 1970's, researchers in certain Scandinavian countries, performing epidemiological studies using case report and cross-sectional methods,^[6] reported that neuropsychiatric *261 symptoms may be induced by long-term exposure to solvents. In 1979, the Danish physician, Arlien-Soborg, coined the phrase "chronic painters' syndrome," in a study done on seventy house painters. The report concluded that the majority of the painters who had been exposed to organic solvents, often through a period with acute intoxication symptoms, had gradually developed signs of a chronic brain syndrome. The symptoms included impaired memory, fatigue, personality change, headaches, and irritability. Arlien-Soborg, et al., "Chronic Painters' Syndrome — Chronic Toxic Encephalopathy in House Painters," *Acta. Neurol. Scand*, 60:149-156 (1979). Other authors, including plaintiffs' expert Dr. Edward Baker, have reported that the Scandinavian studies supported the hypothesis that toxic encephalopathy occurs in individuals heavily exposed to solvents over a period of months to years. See Baker, et al., "The Neurotoxicity of Industrial Solvents: A Review of the Literature," *Am. J. of Indus. Med.*, 8:207-217 (1985).^[7]

As the defendant contends, the Scandinavian studies have been criticized for failing to prove that the painters' symptoms were related to their occupational exposure to organic solvents and for the disappearance of evidence of impairment in twenty re-examined workers. See Errebo-Knudsen and Olsen, "Organic Solvents and Presenile Dementia (The Painters' Syndrome): A Critical Review of the Danish Literature," *The Sci. of the Total Env't*, 48:45-67(1986); Gade et al., "Chronic Painter's Syndrome. A Reanalysis of Psychological Test Data in a Group of Diagnosed Cases," *Acta Neurol. Scand.*, 77:293-306 (1988).

Some studies have likewise questioned the Scandinavian studies. As one report indicates:

Studies outside Scandinavia, mainly cross-sectional clinical studies, have not supplied convincing evidence to support the hypothesis of solvent exposure causing irreversible brain damage... . The reason for this discrepancy might lie in differences of study design, incomparable study populations, insufficient adjustment for confounding factors, and, perhaps most importantly, differences in disease classification.

Rasmussen et al., "Solvent-Induced Chronic Toxic Encephalopathy," *Am. J. Of Indust. Med.*, 23:779-792 (1993); see also Williamson, et al., "A Prospective Cohort Study of the Chronic Effects of Solvent Exposure," *Environmental Res.*, 62:256-271 (1993)("cross sectional studies suffer from problems of possible confounding by a range of unknown factors and also usually from poor estimates of exposure."). Moreover, other studies have reached opposite results. See, e.g., Spurgeon, et al., "Investigation of Dose Related Neurobehavioral Effects in Paintmakers Exposed to Low Levels of Solvents," *Occupational & Environmental Medicine*, 51:626-630 (1994)(cross sectional study of 110 paintmakers resulted in view that "long term exposure at or below current compliance levels does not result in damage to the central nervous system.").

262 Despite the criticisms, textbooks and review articles recognize the diagnosis of toxic encephalopathy. For example, in the chapter entitled "Organic Solvents and Related Compounds" of the *Textbook of Clinical Occupational and Environmental Medicine*, the authors state that "there is currently sufficient support for the association of high long-term solvent exposure with long-lasting psycho-organic symptoms to consider this a *262 clinical reality." Rosenstock and Cullen, at p. 773 (1994).

International and national governmental health organizations also have recognized the syndrome. For example, at the World Health Organization and Nordic Council of Ministers meeting in Copenhagen, Denmark, in June 1985, it was stated that "[c]linical, epidemiological and experimental data indicate that long-term occupational exposure to organic solvents may cause adverse effects in the central and the peripheral nervous systems." It was recommended that further "clinical, experimental and epidemiological studies should be undertaken to gain further insight into the reversibility of the neurotoxic effects induced by the solvents, their health significance and the dose-effect, dose-response relationships." *Id.* at pp. 32-33.

The National Institute for Occupational Safety and Health ("NIOSH") "Current Intelligence Bulletin 48," issued on March 31, 1989, makes similar observations and recommends that producers and users inform their customers, that trade associations and unions warn their workers, and that protective equipment and worker education be used to reduce worker exposure — at least to concentrations specified in exposure lists of OSHA and other organizations. *Id.* at iii-iv.

Accordingly, as the trial court found, numerous epidemiological studies support the diagnosis of toxic encephalopathy from exposure to solvents. While other reports have criticized the epidemiological studies, the diagnosis is recognized in textbooks and journals, as well as by national and world health organizations. It is with this background that we now turn to the legal principles governing the admissibility of scientific evidence.

SCIENTIFIC EVIDENCE

Nearly 75 years ago, the test for determining the admissibility of scientific evidence was established in the landmark federal case of *Frye v. United States*, 293 F. 1013 (D.C. Cir.1923). In *Frye*, which involved a polygraph examination, or lie detector, the court said that scientific evidence will be admissible only if it has "gained general acceptance in the particular field in which it belongs." *Id.* at 1014. This rule, although followed by the vast majority of federal and state jurisdictions, including Tennessee, was often criticized for being too restrictive of relevant evidence, particularly new or "cutting edge" scientific theory, and too vague for uniform application. See e.g., *Symposium on Science and the Rules of Evidence*, 99 F.R.D. 187 (1983)(and extensive authority discussed therein).

The federal courts embarked on a new and less restrictive course with the decision recently in *Daubert v. Merrell Dow Pharmaceuticals*, 509 U.S. 579, 113 S.Ct. 2786, 125 L.Ed.2d 469 (1993), by the U.S. Supreme Court where the Court reversed the 9th Circuit and determined that the "general acceptance" test set forth in *Frye* was superseded by Fed.R.Evid. 702:

If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise.

According to the Court, Rule 702 requires a determination as to "whether the expert is proposing to testify regarding scientific knowledge that will assist the trier of fact to understand or determine a fact in issue." *Daubert*, 509 U.S. at 592, 113 S.Ct. at 2796. This determination requires the trial court to consider "whether the reasoning or methodology underlying the testimony is scientifically valid and of whether the reasoning or methodology properly can be applied to the facts in issue." *Id.* In analyzing scientific validity or reliability, the trial court must focus on "principles and methodology, and not on the conclusions they generate." *Id.*, 509 U.S. at 595, 113 S.Ct. at 2797.

A partial list of factors the Supreme Court deemed relevant to the inquiry included whether the theory or technique has been tested, whether it has been subject to peer review or publication, whether there is a known or potential rate of error, and whether, as formerly required under *Frye*, it is generally accepted in the relevant scientific field. *Id.*, 509 U.S. at 593-94, 113 S.Ct. at *263 2796-98. On remand, the Ninth Circuit Court of Appeals also considered whether the expert proposes to testify about research conducted independent of litigation or whether the expert had formulated an opinion for the express purpose of testifying. *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 43 F.3d 1311, 1317 (9th Cir.)("Daubert II"), cert. denied, _____ U.S. _____, 116 S.Ct. 189, 133 L.Ed.2d 126 (1995).

Daubert's influence was felt in *Joiner v. General Electric Co.*, 78 F.3d 524, 530 (11th Cir.1996), cert. granted ___ U.S. ___, 117 S.Ct. 1243, 137 L.Ed.2d 325 (1997). There, the trial court ruled that the plaintiff could not present expert testimony that his exposure to polychlorinated biphenyls had caused lung cancer and granted the defendant's motion for summary judgment. On appeal, the Eleventh Circuit, applying *Daubert*, emphasized:

In analyzing the admissibility of expert testimony, it is important for trial courts to keep in mind the separate functions of judge and jury, and the intent of *Daubert* to loosen the strictures of *Frye* and make it easier to present legitimate conflicting views of experts for the jury's consideration.

The court stressed the trial court's role was a narrow one:

This gatekeeping role is simply to guard the jury from considering as proof pure speculation presented in the guise of legitimate scientifically-based expert opinion. It is not intended to turn judges into jurors or surrogate scientists. *Thus, the gatekeeping responsibility of the trial courts is not to weigh or choose between conflicting scientific opinions, or to analyze and study the science in question in order to reach its own scientific conclusions from the material in the field. Rather, it is to assure that expert's opinions are based on relevant scientific methods, processes, and data, and not on mere speculation, and that they apply to the facts in issue.*

Id. at 530 (emphasis added). After applying the *Daubert* inquiry and analyzing the principles and methodology underlying the plaintiff's scientific evidence, the Eleventh Circuit Court of Appeals held that the trial court erred in excluding the evidence.

Although the federal courts have decided a new and less restrictive direction was appropriate, state courts are still wrestling with the choice between *Frye* and *Daubert*. For example, in a case involving the exact same parties, issues, and experts as the present case, a Florida state circuit court, applied the *Frye* test, which was retained in that jurisdiction by the Florida Supreme Court, and concluded that the epidemiological studies were inconsistent and that the criticisms of these studies — that the plaintiffs had failed to show the evidence was "generally accepted" in the relevant scientific community — were valid and, therefore, ruled that the evidence was inadmissible. See *Roy Lee Berry v. CSX Transportation, Inc.*, No. 92-2167 (filed April 28, 1995).

On the other hand, in a federal case involving the exact same parties, issues, and experts as the subject case, the federal district court for the Southern District of Georgia applied *Daubert*, and concluded that the evidence was admissible. The district court found that the epidemiological studies supported the plaintiff's claim that exposure can cause impairment, and found that the studies and results were scientifically valid and reliable notwithstanding the criticisms by opposing experts and reports. The court rejected the defendant's claim that the plaintiffs must show causation with a relative risk or odds ratio of 2.0 or greater. See *Bob Allen, et al. v. CSX Transportation, Inc.*, (S.D. Ga., filed Sept. 10, 1996).

THE TENNESSEE STANDARD

After examining the basic legal principles governing the admissibility of scientific evidence and the change in direction by the federal courts, we turn to Tennessee to clarify our standard of admissibility.

In general, questions regarding the admissibility, qualifications, relevancy and competency of expert testimony are left to the discretion of the trial court. *State v. Ballard*, 855 S.W.2d 557, 562 (Tenn. 1993). The trial court's ruling in this regard may only be overturned if the discretion is arbitrarily *264 exercised or abused. *Id.* The specific rules of evidence that govern the issue of admissibility of scientific proof in Tennessee are Tenn. R. Evid. 702 and 703.^[8] The former provides:

If scientific, technical, or other specialized knowledge will substantially assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education may testify in the form of an opinion or otherwise.

And Tenn. R. Evid. 703 states:

The facts or data in the particular case upon which an expert bases an opinion or inference may be those perceived by or made known to the expert at or before the hearing. If of a type reasonably relied upon by experts in the particular field in forming opinions or inferences upon the subject, the facts or data need not be admissible in evidence. The court shall disallow testimony in the form of an opinion or inference if the underlying facts or data indicate lack of trustworthiness.

The plaintiffs contend that the expert testimony in this case is reliable and that it will substantially assist the jury on the issue of causation. The defendant argues that irrespective of *Frye* or *Daubert*, there must be adherence to the strict requirements contained in the language of the rules and also a reasonable standard for proving causation. It contends that the plaintiffs' scientific evidence is unreliable and must be excluded. The defendant argues that an epidemiological study must show a relative risk of greater than 2.0, which several courts have said means that a disease more likely than not was caused by the specific agent or event. See *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 43 F.3d 1311 (9th Cir.1995), cert. denied, U.S., 116 S.Ct. 189, 133 L.Ed.2d 126 (1995); *DeLuca v. Merrell Dow Pharmaceuticals, Inc.*, 791 F. Supp. 1042 (D.N.J. 1992), aff'd, 6 F.3d 778 (3rd Cir.1993). As discussed herein, the factor is certainly relevant but we reject the contention that it should be adopted as matter of law.

Although the advisory comments to Rule 702 indicate that Tennessee has followed the *Frye* test in analyzing the admissibility of scientific evidence, one commentator, recognizing the similarity between Tennessee Rule 702 and Federal Rule Evid. 702, has raised the question of whether the *Frye* test of "general acceptance" should be abolished in Tennessee. N. Cohen, S. Sheppard, and D. Paine, *Tennessee Law of Evidence*, § 401.20 at 124, n. 233. Indeed, as the trial court in this case noted, there is some evidence of a departure from the strict adherence to the *Frye* test by courts in this State.⁹¹

In our view, determining the standard for the admissibility of scientific evidence requires an analysis of the unique language found in Rules 702 and 703 of the Tennessee Rules of Evidence. For instance, Tenn. R. Evid. 702 requires that the scientific evidence "substantially assist the trier of fact," while its federal counterpart requires only that the evidence "assist the trier of fact." Fed. R.Evid. 702. This distinction indicates that the probative force of the testimony must be stronger before it is admitted in Tennessee. See, e.g., Weinstein, *Rule 702 of the Federal Rules of Evidence is Sound; It Should Not Be Amended*, 138 F.R.D. 631, 636 (1991).

265 Similarly, Tenn. R. Evid. 703 states that "[t]he court shall disallow testimony in the form of an opinion or inference if the underlying facts or data indicate lack of trustworthiness." *265 There is no similar restriction in the federal rule. Fed.R.Evid. 703. Thus, as one writer has observed, "the additional language ... [in the Tennessee rule] is obviously designed to encourage trial courts to take a more active role in evaluating the reasonableness of the expert's reliance upon the particular basis for his or her testimony." R. Banks, *Some Comparisons Between the New Tennessee Rules of Evidence and the Federal Rules of Evidence, Part II*, 20 Mem.S.U. L.Rev. 499, 559 (1990). In sum, even though the facts and data need not be admissible, they must be reviewed and found to be trustworthy by the trial court.

Based on the foregoing analysis, we conclude that Tennessee's adoption of Rules 702 and 703 in 1991 as part of the Rules of Evidence supersede the general acceptance test of *Frye*. In Tennessee, under the recent rules, a trial court must determine whether the evidence will substantially assist the trier of fact to determine a fact in issue and whether the facts and data underlying the evidence indicate a lack of trustworthiness. The rules together necessarily require a determination as to the scientific validity or reliability of the evidence. Simply put, unless the scientific evidence is valid, it will not substantially assist the trier of fact, nor will its underlying facts and data appear to be trustworthy, but there is no requirement in the rule that it be generally accepted.

Although we do not expressly adopt *Daubert*, the non-exclusive list of factors to determine reliability are useful in applying our Rules 702 and 703. A Tennessee trial court may consider in determining reliability: (1) whether scientific evidence has been tested and the methodology with which it has been tested; (2) whether the evidence has been subjected to peer review or publication; (3) whether a potential rate of error is known; (4) whether, as formerly required by *Frye*, the evidence is generally accepted in the scientific community; and (5) whether the expert's research in the field has been conducted independent of litigation.

Although the trial court must analyze the science and not merely the qualifications, demeanor or conclusions of experts, the court need not weigh or choose between two legitimate but conflicting scientific views. The court instead must assure itself that the opinions are based on relevant scientific methods, processes, and data, and not upon an expert's mere speculation. See, e.g., *Joiner*, 78 F.3d at 530. The trial court should keep in mind that the preliminary question under Tenn. R. Evid. 104 is one of admissibility of the evidence. Once the evidence is admitted, it will thereafter be tested with the crucible of vigorous cross-examination and countervailing proof. After that occurs, a defendant may, of course, challenge the sufficiency of the evidence by moving for a directed verdict at the appropriate times. See Tenn. R. Civ. P. 50. Yet it is important to emphasize that the weight to be given to stated scientific theories, and the resolution of legitimate but competing scientific views, are matters appropriately entrusted to the trier of fact. See *Joiner*, 78 F.3d at 534-35 (Birch, J., concurring).

We recognize that the burden placed on trial courts to analyze and to screen novel scientific evidence is a significant one. No framework exists that provides for simple and practical application in every case; the complexity and diversity of potential scientific evidence is simply too vast for the application of a single test. See *Developments in the Law — Confronting the New Challenges of Scientific Evidence*, 108 Harv. L.Rev. 1481, 1513-1516 (1995). Nonetheless, the preliminary questions must be addressed by the trial court, see, Tenn. R. Evid. 104, and they must be addressed within the framework of rules 702 and 703.

APPLICATION OF STANDARD

266 The trial court correctly foresaw the trend away from *Frye* and also used the factors set forth in *Daubert* as a framework for analysis. As it observed, the scientific theory that exposure to solvents may cause toxic encephalopathy has been tested frequently over a period of 25 years. Because no precise diagnostic device or biological mechanism can isolate the causal factor, the relevant tests have been epidemiological studies. The experts in this case testified at length about the field of epidemiology and the use of cohort and case-control studies. The experts *266 agreed that epidemiological studies have been used to test the hypothesis that exposure to solvents causes encephalopathy and that numerous studies support a causal relationship. These studies have been reviewed, reconstructed, published in leading journals in the field, and subjected to peer review. Although the "positive" studies have been criticized for failing to account for confounding factors, the diagnosis is recognized in medical textbooks and journals as well as by several national and world health organizations. We also observe that the research in this area, including that of several of the plaintiffs' experts, was conducted independently of this litigation.

Accordingly, we agree with the trial court's finding that the evidence will substantially assist the jury to understand the evidence and to determine a fact in issue. We also agree with the trial court's conclusion that the methodology and principles underlying the scientific evidence are sufficiently trustworthy and reliable to be presented to the trier of fact. The trial court is not required to determine whether it agrees with the evidence and should not substitute its view for the trier of fact. It should allow the jury to consider legitimate but conflicting views about the scientific proof. Provided the evidence is scientifically valid, criticisms of it and opposing views may be elicited on cross examination and/or established in the defendant's case. That is the essence of the lawsuit.

CONCLUSION

We have concluded that the scientific evidence proffered by the plaintiffs satisfies the requirements of Tenn. R. Evid. 702 and 703, and that the trial court did not abuse its discretion in admitting it into evidence. The trial court's order denying the defendant's motion in limine is therefore affirmed and this case is remanded to the trial court for further proceedings. Costs of the appeal are assessed against the defendant.

DROWOTA, REID, BIRCH and HOLDER, JJ., concur.

[1] The particular solvents at issue in this case are: trichloroethane, trichloroethylene, perchloroethylene, and mineral spirits.

[2] Epidemiology is the "study of the distribution and determinants of health-related states and events in populations and the application of this study to control of health problems." *Reference Manual on Scientific Evidence*, Federal Judicial Center, p. 174 (1994)(hereinafter "*Reference Manual*").

There are two general types of epidemiological studies which are used to test a hypothesis: (1) cohort studies and (2) case-control studies. In a cohort study, the epidemiologist identifies a group of individuals who have been exposed to the chemical and another group of individuals who have not been exposed to the chemical. The epidemiologist chooses two groups as nearly identical as possible except for exposure to the chemical. The incidence rates of disease of the exposed and non-exposed groups over a period of time is then observed. A case-control study involves persons who either have the disease (cases) or do not have the disease (controls). The cases and controls are matched for comparison. A determination is made as to whether the individuals in the case and control groups were exposed to the chemical.

[3] After collecting the data either using a cohort or case-control study, epidemiologists typically measure risk using the concepts of "relative risk" and/or "odds ratio." Cohort studies yield a direct measure of the risk of brain damage according to the presence or absence of solvent exposure. This direct measure, known as the relative risk, is the ratio of the incidence of brain damage or "toxic encephalopathy" in the exposed group divided by the rate in the nonexposed group. If the relative risk is 1.0, then there is no association between solvent exposure and brain damage. A relative risk of 4.0 indicates that the risk of disease in the exposed group is four times higher than the risk of disease in the unexposed group. *Reference Manual* at 148. By contrast, case-control studies utilize an odds ratio in calculating risk. An odds ratio is based on a comparison of the odds of having a disease when exposed to a suspected agent and when not exposed. *Reference Manual* at 149. Relative risk and odds ratio are generally similar in most cases.

[4] Baker's report studied among others, Hanninen (1991 & 1979); Baker (1988); Arlien-Soborg (1979); Elofsson (1980); Hane (1977); Bleeker (1991); Bolla (1990); Parkinson (1990); Maizlsih (1985); and Spurgeon (1992).

[5] The plaintiffs' fourth expert, Dr. Michael Kelly, was the examining physician who diagnosed the plaintiffs' toxic encephalopathy. He described the "differential diagnosis" procedure he used in this regard.

[6] Cross-sectional studies involve selection of individuals, regardless of exposure or disease status. Subjects for such studies are chosen either at random or via probability sampling procedures, which allows for the examination of the prevalence of a disease in a representative sample of the population. McCunney, "Epidemiology and Biostatistics," *A Practical Approach to Occupational and Environmental Medicine* (2nd Ed.), at 349. Case reports are not epidemiological studies, but merely reports of individuals who have been exposed to an agent and then report symptoms associated with the disease. Case reports usually precede the institution of formal epidemiological research, although they can be important in determining whether an association exists between an agent and a disease or defect. For example, the medical community became aware of the association between the drug, Thalidomide, used by pregnant women as a sedative and birth defects in their children as a result of case reports.

[7] Other studies referenced by the parties supporting the theory include Axleson, et al., 1976; Hanninen, et al., 1976; Hane, et al., 1977; Harkonen, et al., 1977; Knave, et al., 1978; Mikkelson, 1980; and Gregersen, et al., 1987, among others.

[8] Of course, scientific evidence also must be relevant before it is admissible. As stated in Tenn. R. Evid. Rule 401, "[r]elevant evidence means evidence having any tendency to make the existence of any fact that is of consequence to the determination of the action more probable or less probable than it would be without the evidence."

[9] The trial judge identified four different standards used by Tennessee courts to determine admissibility of scientific evidence: (1) "Scientifically acceptable and accurate for its purpose." *State v. Johnson*, 717 S.W.2d 298 (Tenn. Crim. App. 1986); (2) "Four-prong threshold test involving whether the witness is an expert; whether the subject matter is proper; whether the subject matter conforms to a generally-accepted theory; and whether the probative value of the witness' testimony outweighs its prejudicial effect." *State v. Schimpf*, 782 S.W.2d 186 (Tenn. Crim. App. 1989); (3) "Frye or Tenn. R. Evid. 702 and 703." *State v. Harris*, 866 S.W.2d 583 (Tenn. Crim. App. 1992); and (4) "Analysis under several tests" *State v. Myers*, 1992 WL 297626 (Tenn. Crim. App. 1992).

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