Date: December 23, 2016

To: John Vance
Policy Chief
National Office, DEEOIC

cc: Jeff Kotsch

From: Lynette D. Stokes, PhD, MPH
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Re: White Paper
Hearing Loss (Noise and Solvent Exposure)

The Division of Energy Employees Occupational Illness Compensation Program (DEEOIC) made the policy decision to compensate employees for bilateral hearing loss on November 6, 2008. The policy decision was based on the available scientific literature and results from the population-based occupational epidemiology and biomedical studies published in peer reviewed scientific journals regarding hearing loss.

Based on the review of the scientific literature published in peer reviewed journals identified during the approximate period of 1993 to 2008, the DEEOIC concluded that a consistent relationship between bilateral hearing loss and occupational exposure to organic solvents such as toluene with simultaneous exposure to noise in the workplace had been established in the population-based epidemiologic literature.[1-13]

The results of occupational studies published by Sliwinska-Kowalska[10] in 2004 confirm the observations of previously published studies by *Morata* a decade earlier.[7-8] In the report by Hodgkinson and Prasher[11] who summarized the last forty years of "ototoxic" effects of industrial solvents, it was concluded that "*the combined exposure to solvents and noise has been observed in humans resulting in greater hearing losses than would be expected from exposure to noise and solvents alone*." Further, the conclusions from an international conference[12] held to specifically review the existing science regarding "ototoxicity" of organic solvents alone and in combination with noise concluded "*an additive or synergistic effect occurs in the case of the combined exposure to noise and solvents, significantly increasing the odds ratio of developing hearing loss."*

Permanent hearing loss has been observed in both ears of workers, but the specific frequency (low, moderate or high) has not been established nor has the threshold level of exposure required of organic solvents and noise to produce the hearing deficit. The duration of exposure to both organic solvents and noise required in some studies appears to be twenty years.[10] Hearing deficits were observed at levels of exposure between 75-365 ppm for toluene among printing workers.[13]

In order to compensate as many workers as possible the DEEOIC reviewed the available studies to determine the minimum level of exposure to both noise and solvents necessary to result in additional bilateral hearing loss over and above noise exposure alone:

- Effects were not observed following noise & solvent exposure at 5-years (average) [**toluene exposure < 50ppm**] Ann Occp Hyg 47:493-502, 2003

- Effects were not observed following noise & solvent exposure at 7-years (average) [**toluene exposure < 50ppm**] Scand J Work Envir Health 23:289-298, 1997

- Effects were not observed following noise & solvent exposure at 8-years (average) [**toluene exposure 208 ppm**]
  Inter J Occ Med Envir Health 21(3):191-200, 2008

- Effects **were** observed following noise & solvent exposure with an average of **12.3 years** (average) [**toluene exposure up to 164 ppm**]
  Envir Health Perspective 114(8): 1283-1286, 2006

[a] The review of the studies above is based on the human epidemiologic scientific literature that was evaluated using the principles of relative risk (RR) and testing hypotheses by determining appropriate statistical significance calculated using 95% confidence intervals (CI).

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[a] Gordis states both case-control and cohort studies are designed to determine whether there is an association between exposure to a factor and development of a disease.[14] In cohort studies the definition of relative risk (RR) can be defined as follows; what is the ratio of the risk of disease in exposed individuals to the risk of disease in non-exposed individuals. The ratio is called the relative risk. Interpreting the statistical significance of the relative risk can be determined by testing the null hypothesis with p values or confidence intervals. The definition of the confidence interval and confidence limits can be defined as a range of values determined by the degree of presumed random variability in the data, within which the value of a parameter (i.e., RR) is thought to lie, with the specified level of confidence (i.e., 95%).[15] The boundaries of a confidence interval are the confidence limits. Lilienfeld et al., states if the confidence interval does not contain the value 1.0, the hypothesis that there is no difference in the risk between the two groups (i.e., cases and controls) is statistically rejected.[16] The human epidemiologic scientific literature can be evaluated using the principles of relative risk, and testing hypotheses by determining statistical significance.[14-16]

The DEEOIC policy decision to compensate employees with 10-years of continuous exposure to solvents and simultaneous exposure to noise is based on the specific review of the studies referenced above for the minimal level of both exposures (i.e., solvents and noise levels above 85 dB).

- The assumption is made that the hypothesized mechanism of action (i.e., damage to the outer hair cells in the ear) is the same for all solvents included in the policy directive. The DEEOIC considers this policy and assumption is extremely clamant favorable to compensate employees.

- The mechanism of action of hearing loss based on simultaneous exposure to both solvents and noise is hypothesized in the publication below:

  Inter J Occ Med Envir Health 20(2):215-222, 2007
  Sliwinska – Kowalska, M

1)Rosenberg J, Katz EA. Solvents (Chapter 29) In: Current Occupational & Environmental Medicine, 4th Edition, Joseph LaDou (eds.) New York: McGraw-Hill, 2007 (p.490-491).
2)Rabinowitz PM, Rees TS. Occupational Hearing Loss-hearing loss due to chemicals (Chapter 20.2) In: Textbook of Clinical Occupational and Environmental Medicine, 2nd Edition, Linda Rosenstock, Mark Cullen, Carl Brodkin, Carrie Redlich (eds.), Philadelphia: Elsevier Saunders, 2005 (p.435).
3)Dunn DE, Rabinowitz PM. Noise-hearing loss due to combined exposures to noise and other factors (Chapter 35) In: Textbook of Clinical Occupational and Environmental Medicine, 2nd Edition, Linda Rosenstock, Mark Cullen, Carl Brodkin, Carrie Redlich (eds.), Philadelphia: Elsevier Saunders, 2005 (p.896, 900-901).
4)Meyer JD, McCunney RJ. Occupational Exposure to Noise-risk factors for hearing loss (Chapter 85) In: Environmental and Occupational Medicine, 4th Edition, William Rom, Steven B. Markowitz (eds.), Philadelphia: Lippincott Williams & Wilkins, 2007 (p.1296).
5)Gagnaire F, Langlais C. Relative ototoxicity of 21 aromatic solvents. Arch Toxicol 79:346, 2005.
6)Kim J, et al. Combined effects of noise and mixed solvents exposure on the hearing function among workers in the aviation industry. Indust Health 43:567, 2005.
7)Morata TC, Dunn DE, Kretchmer LW, et al. Effects of occupational exposure to organic solvents and noise on hearing. Scand J Work Environ Health 19:245-254, 1993.
8)Morata TC, Dunn DE, Sieber WK. Occupational exposure to noise and ototoxic organic solvents. Arch Environ Health 49:359-365, 1994.
9)Johnson AC, Nylen PR. Effects of industrial solvents on hearing. Occup Med 10:623-640,1995.
10)Sliwinska-Kowalska M, Szmytke EZ, Szymczak W, et al. Effects of coexposure to noise and mixture of organic solvents on hearing in dockyard workers. J Occup Environ Med 46:30-38, 2004.
11)Hodgkinson L, Prasher D. Effects of industrial solvents on hearing and balance: a review. Noise & Health 8:32, 114-133, 2006.
12)Sliwinska-Kowalska M, Prasher D, Rodrigues CA, et al. Ototoxicity of organic solvents – from scientific evidence to health policy. Int J Occ Med Environ Health 20(2):215-222, 2007.
13)Morata TC, Fiorini AC, Fischer FM, et al. Toluene-induced hearing loss among rotogravure printing workers. Scand J Work Environ Health 23(4):289-298, 1997.
14) Gordis, L. Estimating Risk: Is There an Association? (Chapter 10) In: Epidemiology 2nd Edition, W.B. Saunders Company: New York, New York, 2000 (p. 160)
15) Last JM. A Dictionary of Epidemiology, Abramson, Greenland, Thuriaux, (Associate Editors), Oxford University Press: New York, New York, 1983
16) Lilienfeld AM, Lilienfeld DE. Selected Statistical Procedures (Appendix 1) In: Foundations of Epidemiology, 2nd Edition, Oxford University Press: New York, New York, 1981 (p. 344)