Prevalence of Ototoxic Chemical Exposure, Noise Exposure and Hearing Difficulty Among Workers in the United States, 2023

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Objective: This study estimated the prevalence of hearing difficulty and workplace exposures to ototoxic chemicals and noise within US industries and occupations. **Methods:** This cross-sectional study examined 2023 National Health Interview Survey data for 17,726 workers. Weighted prevalence and adjusted prevalence ratios of self-reported hearing difficulty and self-reported workplace exposures to ototoxic chemicals, noise and a combination of these exposures were estimated. **Results:** Eleven percent of workers reported hearing difficulty. Within the past year, 13% were exposed to ototoxic chemicals, 16% were exposed to noise, and 7% were exposed to both. Twenty-eight percent had a history of noise exposure. **Conclusions:** Workplace hearing hazards are common. This study was the first to report the overall prevalence of ototoxic chemical exposure among US workers. This exposure cannot be overlooked when protecting worker hearing.

Keywords: occupational hearing loss, hazardous noise, ototoxic chemicals, secondhand smoke, mining, construction, manufacturing, surveillance

LEARNING OUTCOMES

- Discuss the impact of ototoxic chemical exposures related to occupational hearing loss.
- Identify industries and occupations with the highest prevalences of exposures to ototoxic chemicals and noise in the workplace.
- Discuss mitigation strategies to reduce workplace exposures and prevent occupational hearing loss.

Within the United States, hearing loss is one of the most prevalent work-related illnesses.[1] Occupational hearing loss (OHL) is caused predominantly by workplace exposures to noise and chemicals that can damage hearing, known as ototoxic chemicals.[2] Ototoxic chemicals (also called ototoxicants if manmade; ototoxins if naturally occurring) can cause OHL in the absence of noise, make the ear more vulnerable to the harmful effects of noise, or both, with possible potentiated or synergistic effects when combined with noise. Ototoxic chemical classes include solvents, heavy metals, nitriles, pharmaceuticals, and asphyxiants.[3–5] These are common chemicals such as industrial cleaners, thinners, paints, lacquers, industrial glues, pesticides, antineoplastic drugs, lead, organic tin compounds, organic cyanides, tobacco smoke, and engine exhaust. Many are commonly found in loud workplaces.[5,6]

Despite the pervasiveness of these chemicals throughout industry and detrimental effects on hearing, there is no national prevalence estimate of worker ototoxic chemical exposure or overall estimates by industry or occupation. Only a few national estimates for specific types of ototoxic chemicals are available and most are old. The National Institute for Occupational Safety and Health (NIOSH) estimated nearly 10 million workers were potentially exposed to organic solvents[7] based on National Occupational Hazard Survey (NOHS) data collected in 1972–1974.[7,8] A follow-on study using 1981–1983 National Occupational Exposure Survey (NOES) data estimated that 5 million workers were co-exposed to noise and at least one of five solvents known to be ototoxic at that time (toluene, xylene, trichloroethylene, styrene and carbon disulfide).[9–11]

There is an estimate for secondhand smoke exposure using 2015 National Health Interview Survey (NHIS) data, which indicates that 10% of workers are exposed overall, and industry and occupation estimates are also provided.[12] Secondhand smoke includes the ototoxic chemicals carbon monoxide, toluene, p-xylene, and ethylbenzene.[13] Finally, a study examined Bureau of Labor Statistics (BLS) numbers of employees within industries, significant losses in hearing recorded on Occupational Safety and Health Administration (OSHA) 300 logs, and 2012–2020 OSHA workplace inspection data and identified the top industries with ototoxicant exposure risk, finding most to be in manufacturing.[14] However, this study only covered select solvents and lead, and was limited by the nonrepresentative nature of how OSHA inspection sites are chosen and the ototoxicants that happened to be measured during these inspections. The BLS/OSHA data study was also limited by the gross underestimate of OSHA 300 log entries for worker hearing loss.[2] In addition, non-noise-exposed workers who are exposed to ototoxic chemicals are not required to receive audiometric testing, so their hearing losses are unlikely to be captured on an OSHA 300 log.

Obtaining benchmark data on worker ototoxicant exposures is critical to identify high risk industries and occupations; especially when also in industries and occupations with high prevalences of noise exposure. In addition to a lack of information on ototoxic chemical exposures, the most recent national estimates for worker hearing

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difficulty and occupational noise exposure are based on data from 2014, the latest year that relevant hearing-related questions were available in a national survey with sufficient sample size to produce estimates by industry and occupation. That data indicated that 25% of US workers (41 million) have a history of occupational noise exposure, with 14% exposed each year (22 million).[15] It is important to produce updated statistics to monitor progress (or regression) in reducing exposure to hearing hazards and worker hearing loss.

The purpose of this study was to estimate the prevalence of hearing difficulty and workplace exposures to ototoxic chemicals and noise within US industries and occupations using data from the 2023 NHIS. Prevalence, adjusted risk compared with a reference industry or occupation, and the attributable fractions of hearing difficulty due to occupational exposures were estimated.

MATERIALS AND METHODS

Study Design and Population

This was a cross-sectional study of 17,726 male and female current and recent workers aged 18+ who participated in the 2023 NHIS adult sample (the entire adult sample included 29,522 participants). The NHIS is a cross-sectional, nationally representative sample of the noninstitutionalized US civilian population.[16] The 2023 survey included sponsored hearing-related questions and was a year when industry and occupation information were captured. Survey participants were identified as current or recent workers if they 1) answered 'Yes' to the question "Last week, did you work for pay at a job or business?"; or 2) answered 'Yes' to the question "Did you have a job or business last week, but were temporarily absent due to illness, vacation, family or maternity leave, or some other reason?"; or 3) answered "Within the past 12 months" to the question "When was the last time you worked for pay at a job or business, even if only for a few days?" Workers who answered that they were 'deaf' to the hearing difficulty question were excluded (89 workers) as this level of hearing impairment is unlikely to have been caused predominately by occupational exposures.[17]

Weighted prevalences and weighted adjusted prevalence ratios (PRs) of self-reported hearing difficulty and self-reported workplace exposures to ototoxic chemicals, noise, and a combination of these exposures were estimated by industry, occupation, and demographic. The PRs are weighted adjusted risk estimates compared with a reference group. Workplace exposure to secondhand smoke was examined combined with other ototoxic chemicals but also separately. The hearing difficulty and occupational exposure questions are described in the next section. NHIS participants reported industry and occupation verbatim and these responses were coded by US Census Bureau coding specialists into 2017 North American Industry Classification System (NAICS) codes and 2018 Standard Occupation Classification (SOC) Codes.[18,19] The covariates of interest were age group, sex, education, race/ethnicity, obesity determined from body mass index (BMI) and smoking status (current, former and never smoker). Races other than 'Hispanic' are all non-Hispanic.

This study adhered to "Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)" guidelines (Supplemental Digital Content, http://links.lww.com/JOM/B982). The 2023 NHIS was approved by the Research Ethics Review Board of the National Center for Health Statistics and the US Office of Management and Budget. All 2023 NHIS participants consented orally prior to participating. This study was reviewed by the Centers for Disease Control and Prevention (CDC), deemed not research, and was conducted consistent with applicable federal law and CDC policy. §§ See, eg, 45 C.F.R. part 46.102(l)(2), 21 C. F.R. part 56; 42 U.S.C. §241(d); 5 U.S.C. §552a; 44 U.S.C. §3501 et seq.

NHIS Outcome and Occupational Exposure Questions

All the data used in this study were self-reported, including the outcome and exposures. The outcome was hearing difficulty, determined from the question below. Workers who identified their hearing ability as "a little trouble hearing," "moderate trouble," or "a lot of trouble" were identified as having hearing difficulty.

These next questions are about your hearing WITHOUT the use of hearing aids or other listening devices.

Without a hearing aid or other listening devices, is your hearing excellent, good, a little trouble hearing, moderate trouble, a lot of trouble, or are you deaf?

Below are the questions for occupational exposures to ototoxic chemicals and secondhand smoke. In this study, workers identified to have ototoxic chemical exposure answered yes to questions A & B, or yes to C, or yes to A, B, and C. All workers with secondhand smoke exposure were included in the estimates for ototoxic chemicals. Workers exposed to secondhand smoke were also examined separately. The "Read if necessary" part of the questions were read to survey respondents if they had trouble understanding the question.

The next set of questions ask about your exposure to chemicals and tobacco smoke in your job.

A. *During the past 12 months, did you work in a job where you were exposed to any of the following: solvents, industrial glues, heavy metals, pesticides or motor engine exhaust?*

** Read if necessary: Solvents are liquids, not including water, used for dissolving other substances, such as dry-cleaning fluids, thinners, components of paints, industrial cleaners and paint removers. Industrial glues are adhesives that include acrylic, epoxy, hot melt, polyurethane, silicone, thermoset and industrial sealants. Heavy metals include lead, nickel, mercury, cadmium, arsenic, chromium, zinc and copper.*

B. *[If YES to A] Were you exposed for 4 or more hours a week?*

C. *During the past 12 months, did you work in a job where you were exposed for 4 or more hours a week to tobacco smoke from other people?*

** Read if necessary: Tobacco smoke includes smoke from cigarettes, cigars, pipes, cigarillos, and hookahs. Do not include e-cigarettes or vaping devices that do not contain tobacco.*

Below are the questions for occupational exposures to noise at any time (hereafter referred to as a history of noise exposure - question D) or exposure in the past 12 months (hereafter referred to as noise exposure - question E).

The next few questions are about your current or previous exposure to loud and very loud sounds or noises. First, we will ask about exposure to loud noises or sounds while working. Loud means so loud that you must speak in a raised voice to be heard.

Have you EVER had a job, or combination of jobs, where you were exposed to loud sounds or noise for 4 or more hours a day, several days a week?

[If YES to D] During the past 12 months, have you had a job, or combination of jobs, where you were exposed to LOUD sounds or noise for 4 or more hours a day, several days a week?

Read if necessary: Loud means so loud that you must speak in a raised voice to be heard.

Statistical Analysis

Analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC) and SUDAAN version 11 (RTI International, Research Triangle Park, NC) statistical software. Weighted prevalence estimates were obtained for the outcome (hearing difficulty) and each occupational exposure using the SAS surveyfreq procedure, incorporating

TABLE 1. Hearing Difficulty, Occupational Exposures to Ototoxic Chemicals and Noise in the Past 12 Months, and a History of Occupational Noise Exposure, by Demographic Among US Workers, 2023[a] (N = 17,726)

				Hearing Difficulty			Ototoxic Chemicals[b]	Secondhand Smoke	Noise	Combined Noise and Ototoxic Chemicals[d]	History of Noise Exposure
Demographics	Unweighted		Weighted	Weighted	PR	PR	Weighted	Weighted	Weighted	Weighted	Weighted
	n	%	*N*	Prevalence (%)		95% CI	Prevalence (%)	Prevalence (%)	Prevalence (%)	Prevalence (%)	Prevalence (%)
Total	17,726	100	170,925,791	11.28			12.77	5.17	15.79	7.01	28.01
Ototoxic chemicals											
Yes	2,082	11.76	21,791,443	17.64	1.59	1.40–1.81	12.77				
No exposure (ref)	15,618	88.24	148,877,944	10.33	Ref		87.23				
Refused/don't know	26										
Secondhand smoke											
Yes	838	4.73	8,833,806	16.29	1.46	1.23–1.74		5.17			
No exposure (ref)	16,879	95.27	161,999,606	10.99	Ref			94.83			
Refused/don't know	9										
Noise											
Yes	2,521	14.25	26,929,990	18.25	1.76	1.58–1.96			15.79		
No exposure (ref)	15,170	85.75	143,659,256	9.94	Ref				84.21		
Refused/don't know	35										
Combined noise and ototoxic chemicals											
Yes	1,102	6.23	11,948,974	19.88	1.71	1.47–2.00				7.01	
Neither or only one exposure (ref)	16,589	93.77	158,640,273	10.60	Ref					93.00	
Refused/don't know	35										
History of noise exposure											
Yes	4,818	27.18	47,828,049	19.10	1.99	1.81–2.19					28.01
No exposure (ref)	12,895	72.75	122,955,762	8.23	Ref						72.00
Refused/don't know	13										
Sex											
Male	8,801	49.65	90,356,866	12.89	1.29	1.18–1.41	18.88	7.43	22.35	11.29	38.70
Female (ref)	8,920	50.32	80,518,391	9.47	Ref		5.91	2.64	8.42	2.19	16.00
Refused/don't know	5										
Age group (years)											
18–25 (ref)	1,851	10.46	28,431,423	5.96	Ref		13.90	7.17	19.32	7.91	25.98
26–35	3,717	21.00	37,488,981	7.93	1.18	0.91–1.52	15.25	7.01	18.94	9.13	30.33
36–45	3,710	20.96	34,987,897	8.65	1.25	0.98–1.59	12.63	4.39	14.46	6.94	27.38
46–55	3,386	19.13	32,632,190	11.71	1.70	1.34–2.15	11.86	4.23	14.08	6.07	26.23
56–65	3,261	18.43	26,312,969	17.93	2.46	1.96–3.09	11.59	3.40	14.57	6.10	29.45
66–75	1,476	8.34	9,090,902	25.41	3.41	2.73–4.26	7.68	3.23	8.41	2.70	29.73
76+	297	1.68	1,745,355	42.26	5.68	4.37–7.37	5.95	3.80[d]	7.12	2.27[d]	28.08
Refused/don't know	28										
Race/ethnicity											
White	11,188	63.12	103,372,557	14.50	2.63	1.94–3.55	13.51	5.00	16.57	7.73	31.05
Black/African American	1,890	10.66	19,969,986	6.25	1.30	0.91–1.87	12.62	6.98	15.02	6.28	26.13
Asian (ref)	1,162	6.56	11,303,082	4.55	Ref		4.81	2.17	7.09	1.56	11.68
Hispanic	3,018	17.03	31,718,513	6.52	1.52	1.09–2.13	13.35	5.31	17.01	7.20	25.47
Other race/ethnicity	468	2.64	4,561,653	10.01	2.27	1.48–3.48	12.37	7.61	14.34	5.93	25.26
Refused/don't know	0										
Education											
<High school diploma	1,019	5.77	12,819,851	7.76	0.74	0.56–0.98	19.81	10.41	22.05	10.94	32.21
High school diploma/GED	3,984	22.57	42,360,358	12.28	1.06	0.95–1.19	18.25	7.84	23.96	10.68	36.36

Continued next page

TABLE 1. *(Continued)*

Demographics	Unweighted *n*	Unweighted %	Weighted *N*	Hearing Difficulty: Weighted Prevalence (%)	Hearing Difficulty: PR	Hearing Difficulty: PR 95% CI	Ototoxic Chemicals[b]: Weighted Prevalence (%)	Secondhand Smoke: Weighted Prevalence (%)	Noise: Weighted Prevalence (%)	Combined Noise and Ototoxic Chemicals[d]: Weighted Prevalence (%)	History of Noise Exposure: Weighted Prevalence (%)
Some college	2,538	14.38	27,845,131	11.87	1.10	0.97–1.26	14.34	5.72	18.83	8.19	31.56
College degree (ref)	10,111	57.28	86,969,476	11.07	Ref		19.81	2.86	9.89	4.22	22.09
Refused/don't know	74										
BMI											
Obese (≥30)	5,944	34.13	57,886,319	13.51	1.29	1.18–1.42	14.82	5.78	18.47	8.32	33.45
Not obese (<30) (ref)	11,474	65.87	110,229,950	10.13	Ref		11.83	4.93	14.44	6.41	25.29
Refused/don't know	308										
Smoking status											
Current smoker	1,863	10.52	17,554,909	15.99	1.54	1.34–1.76	26.35	14.92	27.02	15.40	44.64
Former smoker	3,771	21.30	33,391,250	16.92	1.39	1.24–1.55	16.46	6.23	19.53	9.87	38.73
Never smoker (ref)	12,071	68.18	119,763,993	9.01	Ref		9.73	3.45	13.08	4.95	22.54
Refused/don't know	21										

BMI, body mass index; CI, confidence interval; GED, general education diploma; PR, prevalence ratio (adjusted for sex, age, race/ethnicity, education, BMI, and smoking status).

[a]Data are from the NHIS, 2023 adult sample.

[b]Ototoxic chemical exposure includes secondhand smoke exposure.

[c]Combined exposures include noise, ototoxic chemicals, and secondhand smoke.

[d]This estimate has a relative standard error ≥30% and ≤50% and should be used with caution as it does not meet the standards of reliability/precision.

NHIS sample weights. Estimates with a relative standard error ≥30% and ≤50% and their associated PRs were marked as such and estimates with a relative standard error ≥50% and their associated PRs were not reported. PRs (weighted adjusted risk estimates) with 95% confidence intervals were obtained using the SUDAAN procedure rlogist and adjusted for age group, sex, education, race/ethnicity, BMI, and smoking status.

The PR reference groups were female for sex, 18–25 for age group, Asian for race/ethnicity, college degree for education, not obese for BMI, and never smoker for smoking status, as these groups have lower risks for hearing difficulty. Finance and insurance was designated as the reference industry for the industry analyses, and business and financial operations was assigned as the reference occupation for the occupation analyses, because these were used as the reference groups in previous analyses of NHIS data and have low prevalences of hearing difficulty and occupational exposures.[15,20]

The attributable fraction [AF = (PR − 1)/PR] was calculated for each exposure to identify the number of excess cases of hearing difficulty among the exposed [# excess cases = AF × total weighted prevalence of workers with exposure and hearing difficulty]. When a causal relationship has been established between an exposure and hearing difficulty, the number of excess cases among the exposed is also the number of cases that can be prevented if the exposure is reduced to a safe level. There is an established causal relationship between noise and hearing difficulty.[2] Although a causal relationship has been established between some ototoxic chemicals and hearing difficulty, some chemicals (eg, secondhand smoke) may not cause hearing difficulty on their own, but rather exacerbate the effects of noise. Thus, only the number of excess cases among the exposed can be identified for ototoxic chemicals and secondhand smoke in this study.

RESULTS

Sample demographics of the 17,726 workers are provided in Table 1. About 50% were male and age groups were fairly evenly distributed, except for fewer in the youngest (18–25) and oldest (66–75, 76+) age groups. Most workers were White (63%) and had a college degree (57%). Thirty-four percent were obese, 11% were current smokers, and 21% were former smokers.

Prevalence of Ototoxic Chemical Exposures

Within the past year, 13% of workers were exposed to ototoxic chemicals, including 5% exposed to secondhand smoke (one substance containing ototoxic chemicals). The prevalence of ototoxic chemical exposure was three times higher among men and highest in the youngest age groups (18–25, 26–35). Asian workers had markedly lower exposures than the other races/ethnicities. Ototoxic chemical exposures were slightly lower among workers with some college but were otherwise fairly similar across levels of education. For secondhand smoke, the prevalence of exposure decreased as level of education increased. Obese workers had a slightly higher prevalence of exposure (15%) than those not obese (12%) and current smokers had the highest prevalence of exposure among all the levels of all demographics (26%).

Industry statistics are provided in Table 2. Industries with the highest prevalences of ototoxic chemical exposures were: Mining (49%); combined Mining and Oil and Gas Extraction (OGE) (44%); Construction (30%); Agriculture, Forestry, Fishing and Hunting (AFFH) (29%); Transportation (24%); and Manufacturing (24%). Finance and Insurance had the lowest prevalence of exposure (3%). Figure 1 depicts industries ranked by prevalence of ototoxic chemical exposure. Industries with the highest prevalences of secondhand smoke somewhat coincided: Mining (25%), combined Mining and OGE (22%); Warehousing (17%); Construction (14%); Arts, Entertainment, and Recreation (11%); and Utilities (9%). Secondhand smoke was lowest in Professional, Scientific and Technical services (1%).

TABLE 2. Prevalence of Hearing Difficulty, Occupational Exposures to Ototoxic Chemicals and Noise in the Past 12 Months, and a History of Occupational Noise Exposure, by Industry Among US Workers, 2023[a] (N = 17,726)

				Hearing Difficulty			Ototoxic Chemicals[b]	Secondhand Smoke	Noise	Combined Noise and Ototoxic Chemicals[d]	History of Noise Exposure
Industry (NAICS)	Unweighted *n*	Unweighted %	Weighted *N*	Weighted Prevalence (%)	PR	PR 95% CI	Weighted Prevalence (%)	Weighted Prevalence (%)	Weighted Prevalence (%)	Weighted Prevalence (%)	Weighted Prevalence (%)
All industries	17,726	100	170,925,791	11.28			12.77	5.17	15.79	7.01	28.01
Agriculture, forestry, fishing and hunting (11)	248	1.40	2,410,366	14.29	1.14	0.79–1.63	29.32	7.27	29.90	16.82	43.66
Mining and oil and gas extraction (21)	77	0.43	811,358	17.77[d]	1.49[d]	0.76–2.90	44.28	21.74[d]	52.33	33.21	64.80
Mining (212, 213,113–213115)	68	0.39	714,492	13.75[d]	1.20[d]	0.28–2.48	48.90	24.68[d]	55.84	37.27	65.52[d]
Oil and gas extraction (211, 213111, 213112)	9	0.05	96,866	[e]	[e]		[e]	[e]	[e]	[e]	[e]
Utilities (22)	156	0.88	1,605,063	12.82	1.24	0.76–2.04	17.81	9.30[d]	20.94	12.01	42.67
Construction (23)	1,222	6.89	12,232,196	13.39	1.21	0.93–1.58	29.70	13.72	37.04	19.17	52.45
Manufacturing (31–33)	1,558	8.79	15,233,353	11.87	1.11	0.85–1.46	23.57	7.28	38.28	17.34	51.16
Wholesale trade (42)	314	1.77	3,246,331	11.66	1.07	0.69–1.67	19.60	9.12	18.64	7.98	34.15
Retail trade (44–45)	1,498	8.45	15,664,902	11.70	1.22	0.94–1.60	10.31	3.67	11.40	4.58	24.50
Transportation (48)	751	4.32	7,630,070	10.18	1.01	0.73–1.39	23.98	5.77	21.57	13.81	37.37
Warehousing (49)	107	0.62	1,124,788	14.43	1.94	1.16–3.23	21.74	17.11[d]	32.50	13.63[d]	46.60
Health care and social assistance (62)	2,595	14.64	23,915,455	10.86	1.30	1.00–1.67	4.24	2.28	6.24	0.78	14.73
Services (51, 53–56, 61, 71–72,81, 92)	7,963	45.78	74,720,317	10.80	1.16	0.92–1.46	8.84	3.87	10.39	4.15	22.28
Information (51)	336	1.90	2,964,647	9.58	1.05	0.70–1.57	4.17[d]	2.37[d]	5.78[d]	[e]	20.57
Finance and insurance (52) (ref)	905	5.11	8,127,807	9.16	Ref		2.69	1.93[d]	2.76	[e]	14.27
Real estate and rental and leasing (53)	344	1.94	3,169,483	6.53	0.60	0.38–0.93	10.05	2.81[d]	9.07	6.43	23.31
Professional, scientific and technical services (54)	1,697	9.57	14,991,962	11.06	1.11	0.85–1.45	3.93	0.99[d]	4.82	1.76	17.96
Mgt of companies and enterprises (55)	18	0.10	154,813	[e]	[e]		[e]	[e]	[e]	[e]	[e]
Administrative and support and waste mgt and remediation services (56)	735	4.15	7,452,534	11.58	1.24	0.89–1.72	17.05	7.50	18.54	8.55	32.76
Educational services (61)	1,645	9.28	14,322,440	11.07	1.20	0.92–1.56	3.76	1.10	6.65	1.12[d]	15.08
Arts, entertainment, and recreation (71)	389	2.19	3,715,920	11.77	1.19	0.85–1.68	14.74	11.03	18.89	7.51	32.51
Accommodation and food services (72)	977	5.51	11,245,463	8.51	1.13	0.83–1.53	9.15	7.05	14.79	3.94	24.10
Other services (except public administration) (81)	856	4.83	8,255,809	11.87	1.15	0.85–1.55	20.49	5.37	16.36	10.90	26.66
Public administration (92)	966	5.45	8,447,245	14.58	1.42	1.07–1.89	11.88	4.42	13.60	6.04	30.10
Refused/don't know/not ascertained/military	332										

CI, confidence interval; NAICS, North American Industry Classification System (2017); PR, prevalence ratio (adjusted for sex, age, race/ethnicity, education, BMI, and smoking status).

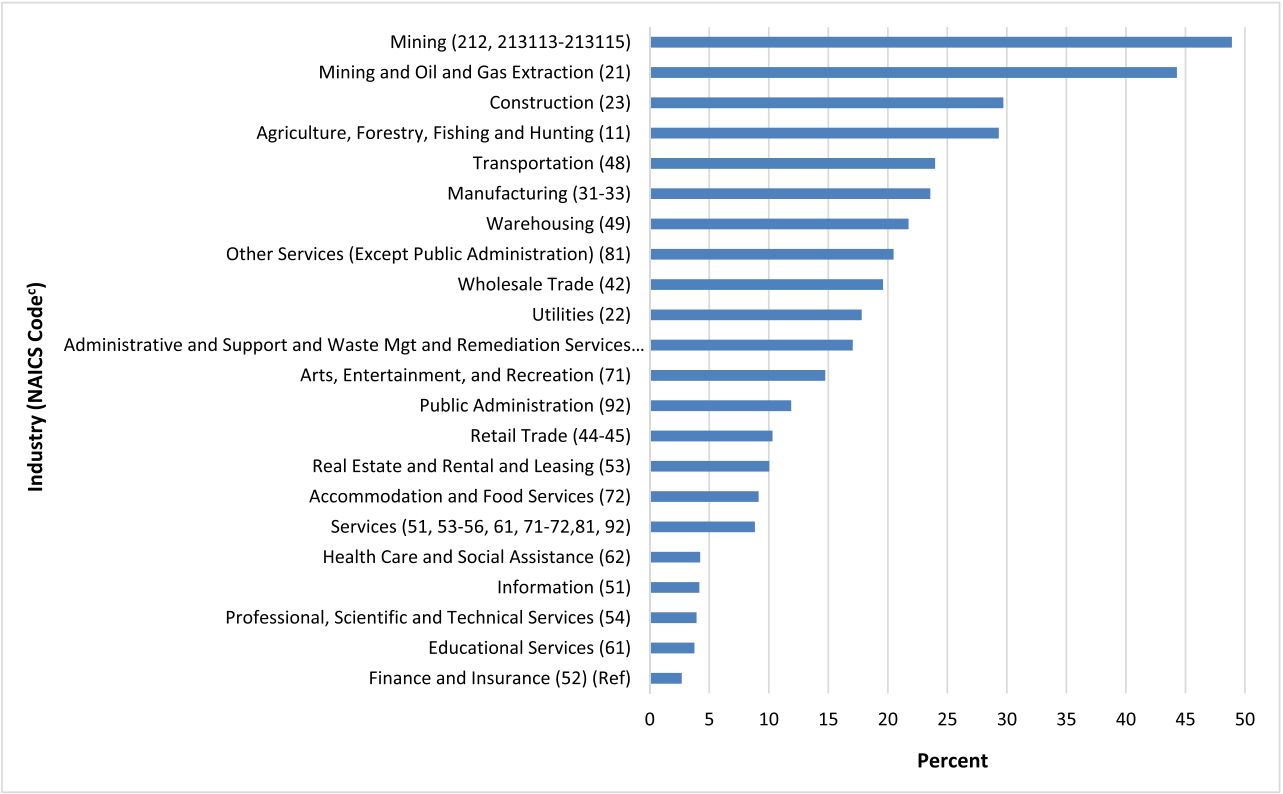
[a]Data are from the NHIS, 2023 adult sample.

[b]Ototoxic chemical exposure includes secondhand smoke exposure.

[c]Combined exposures include noise, ototoxic chemicals, and secondhand smoke.

[d]This estimate has a relative standard error ≥30% and ≤50% and should be used with caution as it does not meet the standards of reliability/precision.

[e]Estimates not shown as they have a relative standard error ≥50% and/or do not meet the standards of reliability/precision.



[a] Ototoxic chemical exposure includes secondhand smoke exposure
[b] Data are from the National Health Interview Survey, 2023 adult sample
[c] NAICS = North American Industry Classification System (2017)

FIGURE 1. Prevalence of occupational ototoxic chemical exposure[a] in the past 12 months by industry among US workers, 2023[b] (*N* = 17,726).

Occupation statistics are provided in Table 3. Occupations with the highest prevalences of ototoxic chemical exposures were: Installation, Maintenance, and Repair (43%); Farming, Fishing, and Forestry (39%); Construction and Extraction (35%); Production (30%); Protective Service (26%); and transportation and Material moving (23%). The same six occupations had the highest prevalences of secondhand smoke, in a different rank order. Ototoxic chemical exposures and secondhand smoke exposures were lowest in Computer and Mathematical (2%) and Educational Instruction and Library (1%), respectively.

Prevalence of Noise Exposure

Sixteen percent of workers were exposed to noise within the past year and 28% had a history of noise exposure (Table 1). The prevalence of noise exposure and a history of noise exposure were twice as high among men. Noise exposure was most prevalent in the youngest age groups (18–25, 26–35), while a history of noise exposure was fairly similar across age groups. Noise exposure and a history of noise exposure were much lower among Asian workers compared to workers of other races/ethnicities. Noise exposure was lower among workers with some college or a college degree, while a history of noise exposure was lower among those with a college degree. Obese workers had a higher prevalence of noise exposure and a history of noise exposure (18% and 33%) than those not obese (14% and 25%). Current and former smokers had the highest prevalences of noise exposure and a history of noise exposure among all levels of all demographics (45% and 39%).

Industries with the highest prevalences of noise exposure were: Mining (56%); combined Mining and OGE (52%); Manufacturing (38%); Construction (37%); warehousing (33%); and AFFH (30%) (Table 2). Figure 2 depicts industries ranked by prevalence of noise exposure. Industries with the highest prevalences of workers with a history of noise exposure were the same industries as those with prevalent noise exposures, in nearly identical order and with higher prevalences: Mining (66%); combined Mining and OGE (65%); Construction (52%); Manufacturing (51%); Warehousing (47%); and AFFH (44%). Noise exposure and a history of noise exposure were lowest in Finance and Insurance (3% and 14% respectively).

Occupations with the highest prevalences of noise exposures were: Production (48%); Construction and Extraction (44%); Installation, Maintenance, and Repair (42%); Farming, Fishing, and Forestry (31%); Transportation and Material Moving (29%); and Protective Service (25%) (Table 3). The same six occupations had the highest prevalences of workers with a history of noise exposure, in a slightly different rank order and with higher prevalences than noise exposure. Noise exposure and a history of noise exposure were lowest in computer and Mathematical (3%), and Community and Social Service (11%), respectively.

Prevalence of Both Ototoxic Chemical and Noise Exposures

Seven percent of workers were exposed to both noise and ototoxic chemicals (Table 1). Males (11%) had more than five times the prevalence of exposure than females (2%), and exposures were highest in the 26–35 age group (9%). All races/ethnicities had prevalences ranging from 6% to 8% except for Asian workers (2%). Exposure prevalences were highest among those with less than a high school diploma (11%) and those with a high school diploma or GED (11%).

TABLE 3. Prevalence of Hearing Difficulty and Occupational Exposures to Ototoxic Chemicals and Noise in the Past 12 Months and a History of Occupational Noise Exposure, by Occupation Among US Workers, 2023[a] (N = 17,726)

	Hearing Difficulty						Ototoxic Chemicals[b]	Secondhand Smoke	Noise	Combined Noise and Ototoxic Chemicals[c]	History of Noise Exposure
Occupation (SOC)	Unweighted *n*	Unweighted %	Weighted *N*	Weighted Prevalence (%)	PR	PR 95% CI	Weighted Prevalence (%)	Weighted Prevalence (%)	Weighted Prevalence (%)	Weighted Prevalence (%)	Weighted Prevalence (%)
All occupations	17,726	100	170,925,791	11.28			12.77	5.17	15.79	7.01	28.01
Management (11)	2,023	11.41	18,107,630	11.80	1.07	0.56–1.34	8.18	2.90	11.63	4.56	25.98
Business and financial operations (13) (ref)	1,230	6.94	10,822,585	9.41	Ref		4.92	1.76	4.84	1.47[d]	17.56
Computer and mathematical (15)	810	4.57	7,297,504	10.93	1.27	0.96–1.69	1.79	0.79[d]	3.32	0.67	19.03
Architecture and engineering (17)	409	2.31	3,573,932	9.14	0.87	0.61–1.23	12.64	3.60	13.02	6.45	31.79
Life, physical, and social science (19)	265	1.49	2,186,818	9.61	1.15	0.74–1.79	14.07	1.95[d]	9.41	3.31[d]	21.91
Community and social service (21)	361	2.04	2,922,570	12.75	1.41	0.96–2.07	2.58[d]	1.98[d]	3.98	e	10.85
Legal (23)	220	1.24	1,823,694	13.08	1.27	0.82–1.97	e	0	e	e	12.33
Educational instruction and library (25)	1,123	6.34	9,993,539	11.83	1.39	1.07–1.79	2.28	0.61[d]	7.48	0.53[d]	15.67
Arts, design, entertainment, sports, and media (27)	384	2.17	3,248,738	12.74	1.27	0.87–1.86	7.52	4.04[d]	9.12	4.18[d]	21.64
Healthcare practitioners and technical (29)	1,173	6.62	10,255,590	10.21	1.26	0.97–1.63	4.67	1.83	6.85	1.06[d]	15.41
Healthcare support (31)	578	3.26	5,757,482	9.51	1.33	0.96–1.83	6.78	4.59	5.45	e	15.48
Protective service (33)	314	1.77	3,374,025	16.16	1.62	1.14–2.29	26.00	14.48	24.56	12.15	44.92
Food preparation and serving related (35)	803	4.53	9,268,770	8.76	1.32	0.98–1.80	8.61	7.43	16.38	3.82	24.73
Building and grounds cleaning and maintenance (37)	588	3.32	5,951,417	11.97	1.33	0.98–1.82	17.59	4.59	20.13	9.92	32.75
Personal care and service (39)	433	2.44	4,465,465	11.54	1.35	0.98–1.85	8.49	5.20	12.72	3.57	19.10
Sales and related (41)	1,300	7.33	12,937,363	10.86	1.12	0.86–1.46	9.98	4.92	7.09	3.40	21.25
Office and administrative support (43)	1,927	10.87	18,277,406	11.10	1.26	0.99–1.60	6.77	3.10	7.32	2.55	18.59
Farming, fishing, and forestry (45)	98	0.55	1,129,841	8.74[d]	0.97[d]	0.48–1.96	38.52	10.86[d]	31.28	19.75	43.86
Construction and extraction (47)	841	4.74	9,388,193	14.11	1.38	1.05–1.81	34.93	15.52	44.29	23.43	58.29
Installation, maintenance, and repair (49)	483	2.72	5,167,754	11.33	1.04	0.76–1.42	43.48	11.26	42.10	28.73	57.14
Production (51)	865	4.88	8,900,628	13.22	1.30	1.01–1.68	30.34	9.98	48.29	22.06	60.44
Transportation and material moving (53)	1,149	6.48	12,609,866	11.19	1.13	0.87–1.46	23.06	8.65	28.56	14.59	42.36
Refused/don't know/not ascertained/military	349										

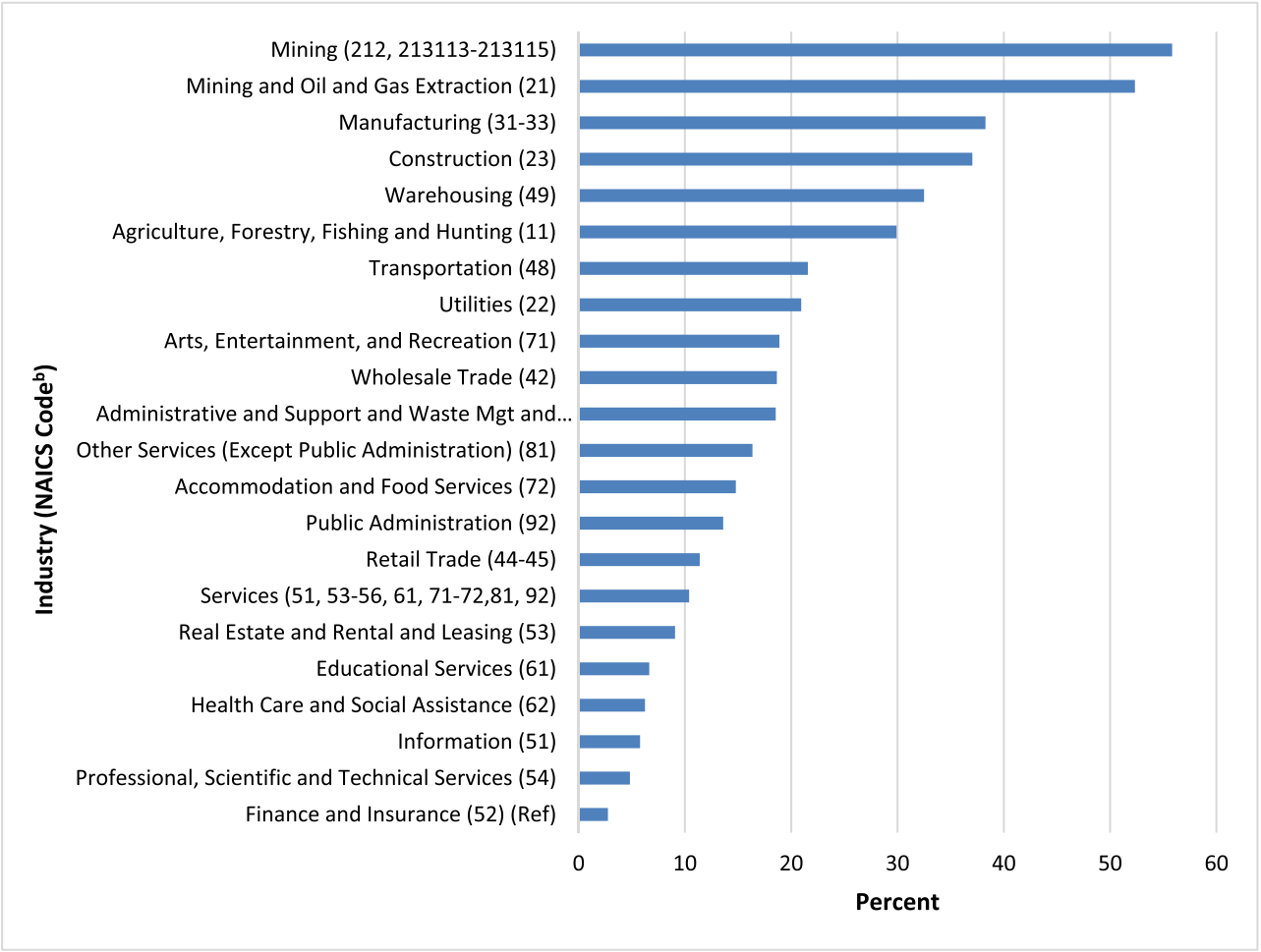
CI, confidence interval; PR, prevalence ratio (adjusted for sex, age, race/ethnicity, education, BMI, and smoking status); SOC, Standard Occupational Classification system (2018).

[a]Data are from the NHIS, 2023 adult sample.

[b]Ototoxic chemical exposure includes secondhand smoke exposure.

[c]Combined exposures include noise, ototoxic chemicals, and secondhand smoke.

[d]This estimate has a relative standard error ≥30% and ≤50% and should be used with caution as it does not meet the standards of reliability/precision.



[a] Data are from the National Health Interview Survey, 2023 adult sample
[b] NAICS = North American Industry Classification System (2017)

FIGURE 2. Prevalence of occupational noise exposure in the past 12 months by industry among US workers, 2023[a] (*N* = 17,726).

Exposure was higher among obese workers (8%) than nonobese workers (6%) and was highest among current smokers (15%).

The industries with the highest combined exposures were the same industries with high prevalences of separate exposures to noise or ototoxic chemicals: mining (37%); combined mining and OGE (33%); construction (19%); manufacturing (17%); AFFH (17%); and transportation (14%) (Table 2). Combined exposures were lowest in Health Care and Social Assistance (1%).

Prevalence of Hearing Difficulty and Risks From Exposures

Eleven percent of workers reported hearing difficulty (Table 1). The prevalence of hearing difficulty was higher in males, increased substantially with age, and was highest among White workers (15%) followed by other race/ethnicity (10%). The prevalence of hearing difficulty was fairly similar across levels of education, with the exception of workers with less than a high school diploma, who had a lower prevalence. The prevalence was higher among obese workers and among former smokers and current smokers.

Industries with the highest prevalences were: combined Mining and OGE (18%); Public Administration (15%); Warehousing (14%); AFFH (14%); Mining (14%); and Construction (13%) (Table 2). Hearing difficulty was lowest in real estate and rental and leasing (7%). The adjusted risk (PR) of having hearing difficulty was significantly higher in Warehousing (94% higher) and Public Administration (42% higher) than in the reference industry. The adjusted risk was significantly lower (40%) in Real Estate and Rental and Leasing than in the reference industry.

TABLE 4. Percent of Hearing Difficulty Cases Attributable to Occupational Exposures to Ototoxic Chemicals and Noise in the Past 12 Months, and to a History of Occupational Noise Exposure Among US Workers, 2023[a] (N = 17,726)

Exposure	Attributable Fraction Among Exposed Workers (%)	Excess Cases Among Exposed Workers
Ototoxic chemicals[b]	37.11	1,426,394
Secondhand smoke	31.51	453,392
Noise	43.18	2,122,267[d]
Combined noise and ototoxic chemicals[b]	41.52	986,301
History of noise exposure	49.75	4,544,626[d]

[a]Data are from the NHIS, 2023 adult sample.
[b]Ototoxic chemical exposure includes secondhand smoke exposure.
[c]Combined exposures include noise, ototoxic chemicals, and secondhand smoke.
[d]Because a causal relationship has been established between noise and hearing difficulty, these are also the number of cases that can be prevented if noise exposure is reduced to a safe level.

Occupations with the highest prevalences of hearing difficulty were as follows: Protective Service (16%); Construction and Extraction (14%); Production (13%); Legal (13%); Community and Social Service (13%); and Arts, Design, Entertainment, Sports, and Media (13%) (Table 3). Hearing difficulty was lowest in Food Preparation and Serving Related (9%). Protective Service, Educational Instruction and Library, Construction and Extraction, and Production had adjusted risks 62%, 39%, 38%, and 30% significantly higher, respectively, than the reference industry.

Attributable Fractions and Excess Cases of Hearing Difficulty

Thirty-seven percent of hearing difficulty cases among workers exposed to ototoxic chemicals were attributable to that exposure, with 1.4 million excess cases among exposed workers (Table 4). For workers exposed to secondhand smoke, 32% of their hearing difficulty cases were attributable to secondhand smoke, with 453,392 excess cases among the exposed. Among workers exposed to noise, 43% of their hearing difficulty cases were attributable to noise, with 2.1 million excess cases among the exposed that could be prevented if the noise was reduced to a safe level. Fifty percent of hearing difficulty cases among workers with a history of noise exposure were attributable to that history, with 4.5 million excess cases among the exposed that could be prevented. Among workers with combined exposures to noise and ototoxic chemicals, 41% of their hearing difficulty cases were attributable to these exposures, with nearly 1 million excess cases among the exposed.

DISCUSSION

This study was the first to report the prevalence of ototoxic chemical exposure among US workers, overall and by industry and occupation, and this exposure is prevalent. Nearly 22 million workers (13%) are exposed, with 1.4 million excess cases of hearing difficulty among these exposed workers attributable to their chemical exposures. This study's survey questions on ototoxic chemicals, which were developed and sponsored by study authors, endeavored to estimate the prevalence of exposure for the most common ototoxic chemicals, across classes. No other similar estimates are available for comparison—the available literature provides estimates for one or two classes of ototoxic chemicals, or for general chemical exposure that includes ototoxicants. One Australian study does cover multiple chemical classes, but its estimates are based on "regular" exposure for any duration at any time during employment (ever exposed) determined by tasks performed rather than reported exposure to specific chemicals.[21] The Lewkowski study (2019) estimates that 42% of the Australian workforce is exposed.[21] This estimate would be expected to be much higher than the present study (13%), which is estimating the prevalence of exposure in the last 12 months and requires 4 or more hours of exposure per week.

Other studies include results for the European Working Conditions Survey, which has collected and reported on working conditions in Europe since 1990, including exposures to broad categories of hazards.[22] In 2015, approximately 11% of European workers reported inhaling vapors such as solvents and thinners, 19% reported inhaling smoke, fumes (eg, exhaust, welding), powder, or dust (eg, mineral, wood), and 14% reported handling chemical products or substances.[23] Another recent study combined US population data with a Canadian job exposure matrix to try to develop broad estimates for chemical agents by demographic.[24] Among other agents, this study estimated exposure prevalences of 13% for nondiesel engine emissions, 8% for diesel emissions, 12% for organic solvents, and 10% for polycyclic aromatic hydrocarbons. In both studies (as in the present study), it is likely that workers had exposures to multiple chemicals. Stephan-Recaido and colleagues (2024) also indicated that exposures were lowest among workers who were female, Asian, and had a bachelor's degree, which is consistent with the present study's findings.[24]

There are no previous studies of ototoxic chemical exposures by occupation and little information by industry, but in general, these chemicals are found to be used ubiquitously across industries and occupations.[3,7,25–28] There is limited information available on exposure to specific chemicals in select industries.

The top industry for exposure was mining. The present study estimated that 25% of workers are exposed to secondhand smoke in mining, the highest of any industry. International and US research also indicates the presence of heavy metals and solvents in mine dust emissions.[29–33] Diesel exhaust exposures are also present and the level of exposure and components differ by mining operation and country.[34–37] Workers in OGE have been found to be exposed to volatile organic compounds (including solvents) and diesel exhaust.[38,39] Solvent exposures in OGE during 1981–1983 were found to include toluene (3%–10% exposed) and xylene (11%–25% exposed).[9]

Regarding Chemicals in Construction, the Center for Construction Research and Training (CPWR) maintains an updated dashboard for exposure and in 2022 reported that 51% of Construction workers were exposed to "contaminants such as pollutants, gases, dust or odors" with frequency "at least once a week/more than half of the time to continually" and 46% were exposed "at least once a month/about half to more than half time."[40,41] The top five occupations within construction for contaminants were as follows: Floor Sanders and Finishers; Insulation Workers, Mechanical; Boilermakers; Pile Driver Operators; and Cement Masons and Concrete Finishers.[40,41] Not all "contaminants" would necessarily be ototoxic. Morata and colleagues [1994] found that solvents and percentages of exposed workers in Construction included trichloroethylene (≤2%), styrene (≤2%–10%), toluene (3%–25%), and xylene (3%–25%).[9] Diesel engine exhaust is also emitted from predominantly off-road vehicles and equipment within Construction.[37] In addition, the present study found that 14% are exposed to secondhand smoke.

Pesticides are the most prominent ototoxicants in Agriculture. About 1 billion pounds of pesticides are applied annually in the US, with 90% applied in agriculture.[42] Nearly 1 million US farms used one or more types of pesticides in 2012, which represented most of the 1.3 million farms with harvested cropland.[43] In addition to pesticides, agriculture, forestry and fishing workers have also been found to be exposed to xylene, toluene and trichloroethylene.[9] Diesel engine exhaust exposure also occurs when driving tractors and using other farm equipment.[44] Exposure concentrations were 44% higher among farmers using diesel tractors/vehicles with open cabs versus enclosed cabs.[44] Finally, 7% in AFFH are exposed to secondhand smoke (present study).

Within Transportation, railroad workers have been found to be exposed to diesel exhaust on or near locomotives.[37] Determinants of exposure in locomotive cabs included where the exhaust stack was located in relation to the cab (in front of or behind the cab), windows being open or closed, and air flow outside the cab.[37] Exposures have also been identified for airline baggage screening workers using diesel-powered tugs, mechanics working on airplane refueling trucks and equipment, and ship dock workers using diesel-powered tugs or lorries for loading and unloading containers.[37] Long-haul truckers are also exposed to exhaust from idling vehicles.[45] Solvent exposures have also been identified within Transportation, including toluene, styrene, trichloroethylene, and xylene.[9]

Within Manufacturing, chemicals are produced and workers can be exposed if not properly protected. Environmental Protection Agency Toxic Substances Control Act risk evaluations identified exposures to carbon tetrachloride, perchloroethylene, and trichloroethylene within Chemical Manufacturing.[46] Exposures to benzene and nitrobenzene have also been documented.[47,48] Solvent exposures in general were found to be pervasive across Manufacturing industries, but prevalences of exposures were particularly high (using 1981–1983 NOES data) within the Standard Industrial Classification (SIC)[49] groups: petroleum refining and related Industries; Chemical and Allied Products; and Rubber and Miscellaneous Plastics Products.[9]

Regarding other workplace exposures, the present study indicates that the overall prevalence of noise exposure has continued to fluctuate, with large numbers of affected workers. Sixteen percent of workers (27 million) were exposed to noise on the job in the past 12 months and 28% had a history of occupational noise exposure (nearly 48 million). This is higher than what was estimated using 2014 NHIS data (14% exposed [22 million workers] with 25% having a history of exposure [41 million workers]).[15] A study examining another nationally representative sample for years 1999–2004 found that 17% were exposed in the prior year (22 million workers).[50] These results also indicate that there has *not* been progress in reducing the number of workers who are exposed to noise on the job.

The industries and occupations with the highest prevalences of noise exposure very closely model past study results. Mining continues to have the highest prevalence of noise exposure.[15,20] The prevalence of a history of noise exposure was higher in 2023 (66%—present study) than in 2014 (61%).[15] Construction, manufacturing, and AFFH continue to have high prevalences of noise exposure and a history of noise exposure. Among occupations, prevalences within production, Construction and Extraction, Installation, Maintenance and Repair, and Protective Service (law enforcement, firefighters) have stayed consistently high.[15]

Of note, the top industries for noise exposure are also the top industries for ototoxic chemical exposure, especially mining, combined Mining and OGE, Construction, Manufacturing, and AFFH. In addition, the same six occupations had the highest prevalences of exposure to ototoxic chemicals, secondhand smoke, noise, combined ototoxic chemical exposures and noise, and a history of noise exposure: Installation, Maintenance, and Repair; Farming, Fishing, and Forestry; Construction and Extraction; Production; Protective Service; and Transportation and Material Moving. Exposure determines risk and these industries and occupations are a top priority for monitoring and intervention.

The Attributable Fractions provided in this study are generally consistent with expectations and confirm the importance of ototoxicant chemical exposures related to hearing difficulty. Noise is the predominant cause of OHL, followed by ototoxic chemical exposure.[2] Results indicate that secondhand smoke exposure in the past 12 months had the lowest AF (32%). Secondhand smoke is only one substance containing ototoxic chemicals and it potentially exacerbates the effect of noise rather than causing hearing difficulty directly. The AF for ototoxic chemical exposure in the past 12 months is higher (37%). It incorporates all queried ototoxicants, including those known to directly cause hearing loss. Noise exposure in the past 12 months has an AF of 43% and is an established cause of hearing difficulty.[2] A history of noise exposure has an AF of 50%. Note that this is lower than the AF found when examining 2014 NHIS data (58%), which may indicate that other factors are now playing a larger role in contributing to hearing difficulty.[15] The AF is lower for noise exposure in the past 12 months than for a history of noise exposure because of the PRs on which these Attributable Fractions are based. The PR for noise in the past 12 months compares the risk of those who have recent noise exposure to those who do not, but there will be workers with a less recent history of noise exposure in the reference group, diluting the difference. The history of noise exposure PR reference group only includes those without a history (no past exposure). The AF for combined noise and ototoxic chemical exposures in the past 12 months (42%) was slightly lower than noise exposures in the past 12 months (43%). A higher AF may have been expected (perhaps between 44% and 49%), but the difference was not substantial. It is possible that most workers exposed to both noise and ototoxicants have somewhat lower levels of either exposure.

The prevalence of worker hearing difficulty estimated using nationally representative data has remained steady over time, with 11% in 2023 (this study), 12% in 2014, 11% in 2007 and 11% in 1997–2003.[15,20,51] This is not unexpected, as hearing difficulty is, in most cases, a permanent condition and improvement in hearing conservation practices or other contributing factors (eg, medical care) would only be able to slowly reduce the overall number over time as affected workers retire/leave the workforce. However, a gross worsening of risk factors could increase the number much more quickly.

"Employers have a responsibility to provide a safe workplace,"[52] so OHL, whether caused by noise, chemicals or a combination of exposures, still falls within the responsibility of the employer. The ototoxic effects of workplace chemicals have received much less attention than noise. This is likely due to 1) the strong established connection between noise and hearing loss, 2) that fact that noise is often present in occupational settings where chemical exposures occur, such that the hearing loss observed is often attributed solely to noise exposure with little or no consideration to the possibility of other exposures; and 3) the audiometric configuration in cases of noise-induced hearing loss and ototoxicity can be identical and therefore easily misattributed to noise. However, this important contributor to worker hearing loss has long been recognized by leaders in the field of hearing loss prevention, including NIOSH, OSHA, the American Industrial Hygiene Association (AIHA), the American Conference of Governmental Industrial Hygienists (ACGIH), and the American College of Occupational and Environmental Medicine (ACOEM).[3,17,53–56]

While current US regulations do not require businesses to monitor the hearing of workers who are exposed to ototoxic chemicals in the absence of noise, this is highly encouraged. Recommendations in the recent AIHA Noise Manual (sixth edition) include re-examining the eligibility requirements for including workers in hearing loss prevention programs to protect workers from chemical exposures or the interaction between noise and chemicals.[54] The ACGIH "highly recommends" yearly audiograms for workers with exposures ≥20% of the threshold limit value for notated chemicals, which include ethyl benzene, styrene, toluene and xylene's p-isomer (dimethylbenzene).[53] OSHA and NIOSH (2018) also state that "…wearing hearing protection and using audiometric testing to detect early signs of hearing loss, even in workers exposed below the action level and ototoxic chemicals below the permissible exposure limit, may prevent hearing loss from their synergistic effects."[3]

The US military has made changes to their hearing conservation programs to address ototoxicant exposures. In addition to required identification and mitigation of chemical exposures, the US Army and US Air Force now monitor the hearing of soldiers and airmen, respectively, and their civilian personnel, if they are exposed to noise *or* ototoxic chemicals.[57,58] Soldiers, airmen and civilian personnel are enrolled in their hearing conservation programs when ototoxicant exposures exceed 50% of the occupational exposure limit.[57,58] The hearing conservation program for the Marines is administered by the Navy. Both the Navy and Marines require the identification and assessment of ototoxic chemical exposure but do not yet require audiometric testing based solely on chemical exposure.[59,60]

While monitoring is important, it is critical to prevent hearing loss before it appears on an audiogram. The hierarchy of controls can be implemented to protect workers from both noise and chemical exposures.[56,61,62] Beginning with the most effective strategies in the hierarchy, first eliminate the noise or change the process that requires the use of an ototoxic chemical. If that is not possible, substitute a quieter piece of equipment or use a nontoxic chemical. Use engineering controls to block or enclose the noise source or increase ventilation. Ensure all equipment is well-maintained. Adjust schedules to reduce the number of workers exposed and their duration of exposure to both noise and chemicals. The least effective strategy in the hierarchy is to make sure all workers are correctly and consistently wearing personal protective equipment, including as appropriate, hearing protection, long sleeves, gloves, aprons, eye protection, and respirators. OHL is preventable.[1]

Strengths and Limitations

This is the first study to estimate the overall prevalence of US worker exposure to ototoxic chemicals, across substance classes, and

by industry, occupation and demographic using a nationally representative sample. It is also the first study to estimate the prevalence of combined exposures to noise and ototoxic chemicals. In addition, this is the first study to provide the prevalence of workers with noise exposure in the past 12 months and with a history of noise exposure, side-by-side, along with ototoxicant exposures. This better elucidated those industries and occupations with multiple exposures that can damage hearing so they can be targeted for intervention. Secondhand smoke exposure was also provided separately so that it can be examined relative to other health outcomes. Lastly, this study provided the AF for each of the exposures to identify the number of excess cases among the exposed, and for the noise-exposed, the number of preventable cases of hearing difficulty if the noise exposure was reduced to a safe level.

This study had limitations. The chemicals that workers were asked about are not an exhaustive list of known ototoxic chemicals. This would make the question unwieldy, and there are also chemicals that are suspected to be ototoxic, but more research is needed to confirm their ototoxic properties. Therefore, it is likely that the 'true' prevalence of ototoxic chemical exposure is higher than reported in this study. Because this is a cross-sectional study, no causation can be inferred between exposures and the outcome. However, causation is already well-established elsewhere between noise and hearing difficulty, and for some of the ototoxic chemicals.[2,3,5]

All survey responses were self-reported, which can introduce bias and inaccuracy. However, most of the NHIS questions have been validated over time. The hearing difficulty question was validated against audiometric threshold estimates,[63] although research indicates that individuals sometimes underreport hearing difficulty, especially if it is mild or affecting the higher frequencies.[64–66] Recall of occupational noise exposure has been found to be valid.[67–69] While the ototoxic chemical exposure questions are new, the secondhand smoke question is very similar to a prior NHIS question and was modified for application to ototoxicity and consistency between the two ototoxic chemical questions. The prior secondhand smoke question was included regularly in NHIS supplements and analyses have been published.[12,70] The ototoxicant question was designed to cover the most common and important ototoxic chemical exposures in terminology that workers could likely recognize and understand.[3,5] There is precedent for using self-report to assess chemical exposures. Examples include the National Health and Nutrition Examination Survey (NHANES) including question(s) every year since 1999 about pesticide exposures, and during 1999–2000 about skin conditions and specific chemical exposures.[71] The US Department of Labor Occupational Information Network (O*NET) has included a question about the frequency of chemical exposures[72] and the Hispanic Community Health Study–Survey of Latinos includes chemical exposure questions on their occupation survey.[73]

Because of a lack of sample size for OGE, no estimates could be provided. OGE does have (HCHS-SOL) some workers at high-risk for hearing loss.[74] Estimates were provided combining OGE with mining in order to achieve some representation for this industry. The NHIS underwent a significant redesign in 2019, including changes to weighting to address nonresponse, which could affect some comparisons to prior findings using pre-2019 NHIS data.[75] Finally, SOC and NAICS are economic classifications which are not designed to group workers with similar exposures together.

CONCLUSIONS

Hearing hazards in the workplace are common. This study was the first to report the prevalence of ototoxic chemical exposure among US workers. Twenty-two million workers are exposed to ototoxic chemicals each year. NIOSH, OSHA, AIHA, ACGIH, and ACOEM have all recognized the importance of this contributor to worker hearing loss.[3,17,53–56] This exposure cannot be overlooked when protecting worker hearing. Both noise and ototoxic chemical exposures can be reduced using the hierarchy of controls. In addition, ACGIH highly recommends annual audiograms for workers with exposures ≥20% of the threshold limit value for certain ototoxicants.[53] The US Army and Air Force also enroll their soldiers and airmen in hearing conservation programs when ototoxicant exposures exceed 50% of the occupational exposure limit.[57,58] The 12 million workers with both noise and ototoxic chemical exposures deserve special attention in hearing conservation programs. More surveillance would also be needed to produce estimates for industries for which there was insufficient sample size.

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