Supplemental Material

Environmental Exposures to Lead, Mercury, and Cadmium and Hearing Loss in Adults and Adolescents: KNHANES 2010-2012

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Study population

An additional 354 participants (328 adults and 26 adolescents) had missing data on covariates and were not included in the analysis: missing data on occupational noise (27 adults), recreational noise (44 adults and 13 adolescents), firearm noise (35 adults and 12 adolescents), socio-behavioral factors of education, income, BMI, and cigarette smoke (142 adults and 12 adolescents), clinical factors of diabetes and hypertension (189 adults). Finally, 6,040 participants (5,187 adults and 853 adolescents) were included for the analysis.

Table S1. ORs (95% CIs) of hearing loss[a] (>25dB) by blood lead, mercury, and cadmium levels in adults (*n*=5,187)

Variables	No. hearing loss/ No. participants	Single-pollutant model		Multi-pollutant model	
Speech-frequency PTA[b]					
Lead					
Per doubling of lead	1124/5187	1.15	(0.94, 1.41)	1.12	(0.91, 1.37)
Lead Quartile (*µg/dL*)					
Q 1 (0.327-1.593)	170/1296	1	(Reference)	1	(Reference)
Q 2 (1.594-2.146)	204/1296	0.94	(0.65, 1.35)	0.92	(0.64, 1.33)
Q 3 (2.148-2.822)	330/1298	1.29	(0.92, 1.78)	1.26	(0.91, 1.75)
Q 4 (2.823-26.507)	420/1297	1.25	(0.87, 1.79)	1.21	(0.85, 1.74)
P-Trend		*0.066*		*0.092*	
Mercury					
Per doubling of mercury	1124/5187	0.96	(0.84, 1.08)	0.93	(0.81, 1.05)
Mercury Quartile (*µg/L*)					
Q 1 (0.363-2.378)	284/1296	1	(Reference)	1	(Reference)
Q 2 (2.379-3.528)	250/1297	0.84	(0.61, 1.17)	0.82	(0.59, 1.14)
Q 3 (3.529-5.369)	267/1296	0.79	(0.58, 1.09)	0.75	(0.54, 1.05)
Q 4 (5.370-60.678)	323/1298	0.84	(0.63, 1.12)	0.78	(0.58, 1.05)
P-Trend		*0.221*		*0.100*	
Cadmium					
Per doubling of cadmium	1124/5187	1.18	(1.00, 1.39)	1.18	(0.99, 1.40)
Cadmium Quartile (*µg/L*)					
Q 1 (0.068-0.689)	140/1293	1	(Reference)	1	(Reference)
Q 2 (0.690-1.033)	255/1300	1.04	(0.73, 1.49)	1.04	(0.73, 1.50)
Q 3 (1.035-1.470)	340/1299	1.22	(0.86, 1.72)	1.22	(0.87, 1.73)
Q 4 (1.471-6.422)	389/1295	1.30	(0.88, 1.91)	1.29	(0.87, 1.90)
P-Trend		*0. 117*		*0.141*	
High-frequency PTA[c]					
Lead					
Per doubling of lead	1124/5187	1.30	(1.08, 1.57)	1.25	(1.04, 1.50)
Lead Quartile (*µg/dL*)					
Q 1 (0.327-1.593)	276/1296	1	(Reference)	1	(Reference)
Q 2 (1.594-2.146)	420/1296	1.13	(0.83, 1.53)	1.11	(0.82, 1.51)
Q 3 (2.148-2.822)	587/1298	1.35	(1.00, 1.81)	1.32	(0.99, 1.78)
Q 4 (2.823-26.507)	810/1297	1.70	(1.25, 2.31)	1.64	(1.21, 2.24)
P-Trend		*<0.001*		*<0.001*	
Mercury					
Per doubling of mercury	1124/5187	0.98	(0.87, 1.09)	0.94	(0.84, 1.05)
Mercury Quartile (*µg/L*)					
Q 1 (0.363-2.378)	469/1296	1	(Reference)	1	(Reference)
Q 2 (2.379-3.528)	460/1297	0.89	(0.68, 1.16)	0.85	(0.65, 1.12)
Q 3 (3.529-5.369)	524/1296	0.83	(0.63, 1.08)	0.77	(0.59, 1.02)
Q 4 (5.370-60.678)	640/1298	0.89	(0.68, 1.17)	0.80	(0.61, 1.06)
P-Trend		*0.382*		*0.091*	
Cadmium					
Per doubling of cadmium	1124/5187	1.25	(1.08, 1.44)	1.21	(1.04, 1.40)
Cadmium Quartile (*µg/L*)					
Q 1 (0.068-0.689)	289/1293	1	(Reference)	1	(Reference)
Q 2 (0.690-1.033)	489/1300	1.10	(0.81, 1.49)	1.07	(0.78, 1.45)
Q 3 (1.035-1.470)	645/1299	1.43	(1.06, 1.93)	1.36	(1.01, 1.83)
Q 4 (1.471-6.422)	670/1295	1.47	(1.05, 2.05)	1.34	(0.96, 1.88)
P-Trend		*0.007*		*0.031*	

Models were adjusted for age, age², sex, education, BMI, cigarette smoke, current diagnosis of hypertension, current diagnosis of diabetes, occupational noise, recreational noise, and firearm noise. For the multi-pollutant models, effect estimates for each metal were computed while the other two metal variables were included as covariates.

[a] Hearing loss was defined as pure tone average >25dB.
[b] Speech-frequency PTA at 0.5, 1, 2, and 4 kHz.
[c] High-frequency PTA at 3, 4, and 6 kHz.

Table S2. Change (95% CIs) in hearing thresholds (dB) by blood lead, mercury, and cadmium levels in adults (*n*=5,187)

Variables	No.	Single-pollutant model		Multi-pollutant model	
Speech-frequency PTA[a]					
Lead					
Per doubling of lead		1.08	(0.26, 1.89)	1.02	(0.17, 1.88)
Lead Quartile *(µg/dL)*					
Q 1 (0.327-1.593)	1296	0	(Reference)	0	(Reference)
Q 2 (1.594-2.146)	1296	0.12	(-0.85, 1.09)	0.12	(-0.87, 1.11)
Q 3 (2.148-2.822)	1298	1.18	(0.01, 2.34)	1.17	(-0.02, 2.36)
Q 4 (2.823-26.507)	1297	1.96	(0.68, 3.25)	1.94	(0.60, 3.29)
P-Trend		*0.001*		*0.002*	
Mercury					
Per doubling of mercury		-0.26	(-0.81, 0.30)	-0.41	(-0.98, 0.15)
Mercury Quartile *(µg/L)*					
Q 1 (0.363-2.378)	1296	0	(Reference)	0	(Reference)
Q 2 (2.379-3.528)	1297	-0.20	(-1.37, 0.96)	-0.31	(-1.47, 0.84)
Q 3 (3.529-5.369)	1296	-0.76	(-1.88, 0.36)	-0.97	(-2.10, 0.16)
Q 4 (5.370-60.678)	1298	-0.45	(-1.70, 0.79)	-0.81	(-2.08, 0.47)
P-Trend		*0.330*		*0.124*	
Cadmium					
Per doubling of cadmium		0.61	(-0.01, 1.22)	0.50	(-0.14, 1.13)
Cadmium Quartile *(µg/L)*					
Q 1 (0.068-0.689)	1293	0	(Reference)	0	(Reference)
Q 2 (0.690-1.033)	1300	-0.24	(-1.28, 0.79)	-0.30	(-1.32, 0.73)
Q 3 (1.035-1.470)	1299	0.47	(-0.67, 1.61)	0.33	(-0.83, 1.49)
Q 4 (1.471-6.422)	1295	0.90	(-0.48, 2.29)	0.62	(-0.78, 2.03)
P-Trend		*0.115*		*0.275*	
High-frequency PTA[b]					
Lead					
Per doubling of lead		1.83	(0.76, 2.89)	1.87	(0.74, 3.00)
Lead Quartile *(µg/dL)*					
Q 1 (0.327-1.593)	1296	0	(Reference)	0	(Reference)
Q 2 (1.594-2.146)	1296	0.10	(-1.22, 1.42)	0.20	(-1.14, 1.54)
Q 3 (2.148-2.822)	1298	1.68	(0. 21, 3.15)	1.81	(0.30, 3.32)
Q 4 (2.823-26.507)	1297	3.50	(1.71, 5.30)	3.69	(1.83, 5.56)
P-Trend		*<0.001*		*<0.001*	
Mercury					
Per doubling of mercury		-0.28	(-1.05, 0.49)	-0.48	(-1.26, 0.30)
Mercury Quartile *(µg/L)*					
Q 1 (0.363-2.378)	1296	0	(Reference)	0	(Reference)
Q 2 (2.379-3.528)	1297	-0.32	(-1.80, 1.17)	-0.46	(-1.93, 1.02)
Q 3 (3.529-5.369)	1296	-1.10	(-2.56, 0.37)	-1.37	(-2.84, 0.09)
Q 4 (5.370-60.678)	1298	-0.89	(-2.60, 0.82)	-1.41	(-3.16, 0.34)
P-Trend		*0.200*		*0.058*	
Cadmium					
Per doubling of cadmium		0.48	(-0.33, 1.29)	0.22	(-0.62, 1.06)
Cadmium Quartile *(µg/L)*					
Q 1 (0.068-0.689)	1293	0	(Reference)	0	(Reference)
Q 2 (0.690-1.033)	1300	-0.69	(-2.20, 0.82)	-0.81	(-2.31, 0.69)
Q 3 (1.035-1.470)	1299	0.36	(-1.35, 2.08)	0.11	(-1.66, 1.87)
Q 4 (1.471-6.422)	1295	0.58	(-1.31, 2.48)	0.04	(-1.88, 1.95)
P-Trend		*0.319*		*0.742*	

Models were adjusted for age, age[2], sex, education, BMI, cigarette smoke, current diagnosis of hypertension, current diagnosis of diabetes, occupational noise, recreational noise, and firearm noise. For the multi-pollutant models, effect estimates for each metal were computed while the other two metal variables were included as covariates.

PTA, Pure tone average.

[a] Speech-frequency PTA at 0.5, 1, 2, and 4 kHz.

[b] High-frequency PTA at 3, 4, and 6 kHz.

Table S3. ORs (95% CIs) of hearing loss [a] (>15dB) by blood lead, mercury, and cadmium levels in adolescents (*n*=853)

Variables	No. hearing loss/ No. participants	Single-pollutant model		Multi-pollutant model	
Speech-frequency PTA[b]					
Lead					
Per doubling of lead	48/853	1.20	(0.48, 3.05)	1.09	(0.40, 2.97)
Lead Quartile *(µg/dL)*					
Q 1 (0.260-0.975)	11/213	1	(Reference)	1	(Reference)
Q 2 (0.978-1.260)	12/213	1.17	(0.41, 3.32)	1.12	(0.39, 3.18)
Q 3 (1.261-1.557)	13/213	1.08	(0.38, 3.08)	0.82	(0.28, 2.40)
Q 4 (1.562-5.904)	12/214	1.24	(0.34, 4.49)	0.91	(0.24, 3.44)
P-Trend		*0.803*		*0.949*	
Mercury					
Per doubling of mercury	48/853	1.01	(0.53, 1.91)	0.97	(0.51, 1.83)
Mercury Quartile *(µg/L)*					
Q 1 (0.555-1.488)	13/213	1	(Reference)	1	(Reference)
Q 2 (1.490-1.956)	10/213	1.00	(0.36, 2.75)	1.00	(0.36, 2.79)
Q 3 (1.960-2.683)	11/214	0.60	(0.21, 1.75)	0.56	(0.19, 1.71)
Q 4 (2.687-8.409)	14/213	1.20	(0.41, 3.54)	1.15	(0.39, 3.38)
P-Trend		*0.901*		*0.968*	
Cadmium					
Per doubling of cadmium	48/853	1.41	(0.93, 2.14)	1.40	(0.88, 2.20)
Cadmium Quartile *(µg/L)*					
Q 1 (0.010-0.245)	12/214	1	(Reference)	1	(Reference)
Q 2 (0.246-0.341)	9/213	0.96	(0.33, 2.76)	0.96	(0.33, 2.83)
Q 3 (0.342-0.495)	9/213	0.93	(0.33, 2.66)	0.91	(0.30, 2.74)
Q 4 (0.496-2.067)	18/213	2.39	(0.98, 5.83)	2.53	(1.02, 6.28)
P-Trend		*0.083*		*0.088*	
High-frequency PTA[c]					
Lead					
Per doubling of lead	95/853	1.26	(0.73, 2.16)	1.17	(0.68, 2.01)
Lead Quartile *(µg/dL)*					
Q 1 (0.260-0.975)	20/213	1	(Reference)	1	(Reference)
Q 2 (0.978-1.260)	20/213	0.89	(0.39, 2.03)	0.88	(0.37, 2.07)
Q 3 (1.261-1.557)	31/213	1.88	(0.83, 4.25)	1.65	(0.67, 4.05)
Q 4 (1.562-5.904)	24/214	1.38	(0.63, 3.02)	1.17	(0.49, 2.81)
P-Trend		*0.181*		*0.377*	
Mercury					
Per doubling of mercury)	95/853	0.73	(0.45, 1.20)	0.70	(0.43, 1.15)
Mercury Quartile *(µg/L)*					
Q 1 (0.555-1.488)	32/213	1	(Reference)	1	(Reference)
Q 2 (1.490-1.956)	20/213	0.64	(0.30, 1.36)	0.55	(0.26, 1.18)
Q 3 (1.960-2.683)	17/214	0.34	(0.16, 0.74)	0.30	(0.13, 0.66)
Q 4 (2.687-8.409)	26/213	0.58	(0.27, 1.26)	0.52	(0.25, 1.09)
P-Trend		*0.107*		*0.072*	
Cadmium					
Per doubling of cadmium	95/853	1.54	(1.12, 2.11)	1.55	(1.11, 2.16)
Cadmium Quartile *(µg/L)*					
Q 1 (0.010-0.245)	20/214	1	(Reference)	1	(Reference)
Q 2 (0.246-0.341)	17/213	1.06	(0.46, 2.46)	0.99	(0.43, 2.27)
Q 3 (0.342-0.495)	20/213	1.51	(0.68, 3.37)	1.50	(0.68, 3.33)
Q 4 (0.496-2.067)	38/213	3.03	(1.44, 6.40)	2.98	(1.37, 6.49)
P-Trend		*0.003*		*0.004*	

Models were adjusted for age, age^2, sex, education, BMI, cigarette smoke, recreational noise, and firearm noise. For the multi-pollutant models, effect estimates for each metal were computed while the other two metal variables were included as covariates.

[a] Hearing loss was defined as pure tone average >15dB.

[b] Speech-frequency at 0.5, 1, 2, and 4 kHz.

[c] High-frequency PTA at 3, 4, and 6 kHz.

Table S4. Change (95% CIs) in hearing thresholds (dB) by blood lead, mercury, and cadmium levels in adolescents (*n*=853)

Variables	No.	Single-pollutant model		Multi-pollutant model	
Speech-frequency PTA[a]					
Lead					
Per doubling of lead		0.54	(-0.27, 1.35)	0.52	(-0.36, 1.40)
Lead Quartile (*μg/dL*)					
Q 1 (0.260-0.975)	213	0	(Reference)		(Reference)
Q 2 (0.978-1.260)	213	1.08	(-0.33, 2.48)	1.02	(-0.36, 2.40)
Q 3 (1.261-1.557)	213	0.97	(-0.16, 2.11)	0.81	(-0.33, 1.94)
Q 4 (1.562-5.904)	214	1.02	(-0.27, 2.31)	0.78	(-0.57, 2.14)
P-Trend		*0.148*		*0.258*	
Mercury					
Per doubling of mercury		0.14	(-0.60, 0.88)	0.10	(-0.64, 0.85)
Mercury Quartile (*μg/L*)					
Q 1 (0.555-1.488)	213	0	(Reference)		(Reference)
Q 2 (1.490-1.956)	213	-0.06	(-1.42, 1.30)	-0.10	(-1.47, 1.27)
Q 3 (1.960-2.683)	214	-0.59	(-1.75, 0.57)	-0.62	(-1.77, 0.53)
Q 4 (2.687-8.409)	213	0.86	(-0.57, 2.29)	0.80	(-0.64, 2.25)
P-Trend		*0.351*		*0.407*	
Cadmium					
Per doubling of cadmium		0.11	(-0.60, 0.82)	0.03	(-0.72, 0.79)
Cadmium Quartile (*μg/L*)					
Q 1 (0.010-0.245)	214	0	(Reference)		(Reference)
Q 2 (0.246-0.341)	213	0.25	(-1.31, 1.82)	0.29	(-1.20, 1.79)
Q 3 (0.342-0.495)	213	0.14	(-1.35, 1.63)	0.08	(-1.38, 1.54)
Q 4 (0.496-2.067)	213	0.68	(-0.81, 2.18)	0.65	(-0.82, 2.13)
P-Trend		*0.418*		*0.568*	
High-frequency PTA[b]					
Lead					
Per doubling of lead		1.03	(0.03, 2.04)	1.11	(0.05, 2.18)
Lead Quartile (*μg/dL*)					
Q 1 (0.260-0.975)	213	0	(Reference)	0	(Reference)
Q 2 (0.978-1.260)	213	1.32	(-0.15, 2.79)	1.27	(-0.21, 2.75)
Q 3 (1.261-1.557)	213	1.49	(0.03, 2.94)	1.40	(-0.05, 2.86)
Q 4 (1.562-5.904)	214	1.65	(0.20, 3.10)	1.52	(0.04, 2.99)
P-Trend		*0.030*		*0.043*	
Mercury					
Per doubling of mercury		-0.35	(-1.17, 0.47)	-0.41	(-1.23, 0.42)
Mercury Quartile (*μg/L*)					
Q 1 (0.555-1.488)	213	0	(Reference)	0	(Reference)
Q 2 (1.490-1.956)	213	-0.16	(-1.79, 1.46)	-0.30	(-1.92, 1.32)
Q 3 (1.960-2.683)	214	-1.38	(-2.84, 0.08)	-1.41	(-2.86, 0.03)
Q 4 (2.687-8.409)	213	0.07	(-1.65, 1.79)	-0.08	(-1.82, 1.66)
P-Trend		*0.770*		*0.679*	
Cadmium					
Per doubling of cadmium		-0.04	(-0.84, 0.76)	-0.17	(-1.01, 0.66)
Cadmium Quartile (*μg/L*)					
Q 1 (0.010-0.245)	214	0	(Reference)	0	(Reference)
Q 2 (0.246-0.341)	213	0.43	(-1.24, 2.11)	0.39	(-1.23, 2.00)
Q 3 (0.342-0.495)	213	0.66	(-1.01, 2.32)	0.55	(-1.08, 2.19)
Q 4 (0.496-2.067)	213	0.62	(-1.15, 2.38)	0.45	(-1.25, 2.15)
P-Trend		*0.478*		*0.670*	

Models were adjusted for age, age^2, sex, education, BMI, cigarette smoke, recreational noise, and firearm noise. For the multi-pollutant models, effect estimates for each metal were computed while the other two metal variables were included as covariates.

PTA, Pure tone average

[a] Speech-frequency PTA at 0.5, 1, 2, and 4 kHz.

[b] High-frequency PTA at 3, 4, and 6 kHz.

Table S5. ORs (95% CIs) of hearing loss (>25dB) by blood lead, mercury, and cadmium levels stratified by adult age groups at single-pollutant models in adults (n=5,187)

Age strata	20-39 years (n=2,031)	40-59 years (n=2,101)	60-87 years (n=1,055)	p for interaction by age strata
Speech-frequency PTA[a]				
Lead				
Per doubling of lead	0.78 (0.41, 1.48)	1.33 (1.05, 1.70)	1.06 (0.72, 1.57)	0.475
Lead Quartile (μg/dL)				
Q 1 (0.327-1.593)	1 (Reference)	1 (Reference)	1 (Reference)	
Q 2 (1.594-2.146)	0.45 (0.23, 0.88)	0.97 (0.59, 1.59)	1.32 (0.64, 2.74)	
Q 3 (2.148-2.822)	0.67 (0.33, 1.39)	1.45 (0.91, 2.30)	1.65 (0.89, 3.05)	
Q 4 (2.823-26.507)	0.90 (0.34, 2.39)	1.33 (0.85, 2.06)	1.46 (0.74, 2.88)	
P-Trend	0.819	0.069	0.235	0.303
Mercury				
Per doubling of mercury	0.91 (0.59, 1.39)	0.98 (0.83, 1.15)	0.92 (0.75, 1.14)	0.865
Mercury Quartile (μg/L)				
Q 1 (0.363-2.378)	1 (Reference)	1 (Reference)	1 (Reference)	
Q 2 (2.379-3.528)	0.55 (0.29, 1.05)	0.96 (0.61, 1.49)	0.79 (0.45, 1.41)	
Q 3 (3.529-5.369)	0.65 (0.30, 1.40)	0.90 (0.60, 1.34)	0.71 (0.40, 1.27)	
Q 4 (5.370-60.678)	0.84 (0.35, 2.03)	0.87 (0.58, 1.32)	0.76 (0.45, 1.28)	
P-Trend	0.697	0.483	0.263	0.910
Cadmium				
Per doubling of cadmium	1.09 (0.74, 1.62)	1.21 (0.98, 1.49)	1.16 (0.85, 1.57)	0.636
Mercury Quartile (μg/L)				
Q 1 (0.068-0.689)	1 (Reference)	1 (Reference)	1 (Reference)	
Q 2 (0.690-1.033)	1.52 (0.66, 3.53)	1.02 (0.62, 1.66)	0.72 (0.37, 1.42)	
Q 3 (1.035-1.470)	1.06 (0.37, 2.99)	1.30 (0.81, 2.07)	1.02 (0.52, 1.99)	
Q 4 (1.471-6.422)	0.94 (0.32, 2.75)	1.37 (0.84, 2.24)	1.06 (0.53, 2.11)	
P-Trend	0.834	0.107	0.403	0.856
High-frequency PTA[b]				
Lead				
Per doubling of lead	0.96 (0.67, 1.37)	1.44 (1.14, 1.81)	1.60 (0.94, 2.70)	0.046
Lead Quartile (μg/dL)				
Q 1 (0.327-1.593)	1 (Reference)	1 (Reference)	1 (Reference)	
Q 2 (1.594-2.146)	0.72 (0.46, 1.12)	1.34 (0.90, 2.01)	1.73 (0.72, 4.13)	
Q 3 (2.148-2.822)	0.75 (0.45, 1.25)	1.55 (1.07, 2.26)	2.97 (1.29, 6.83)	
Q 4 (2.823-26.507)	1.21 (0.69, 2.13)	1.92 (1.29, 2.84)	2.45 (1.14, 5.23)	
P-Trend	0.603	0.001	0.010	0.041
Mercury				
Per doubling of mercury	0.94 (0.74, 1.20)	0.99 (0.87, 1.14)	0.99 (0.71, 1.37)	0.693
Mercury Quartile (μg/L)				
Q 1 (0.363-2.378)	1 (Reference)	1 (Reference)	1 (Reference)	
Q 2 (2.379-3.528)	0.82 (0.52, 1.31)	0.95 (0.65, 1.38)	0.68 (0.30, 1.56)	
Q 3 (3.529-5.369)	1.02 (0.63, 1.64)	0.73 (0.51, 1.06)	1.00 (0.46, 2.18)	
Q 4 (5.370-60.678)	0.85 (0.48, 1.50)	0.89 (0.62, 1.28)	0.97 (0.45, 2.08)	
P-Trend	0.791	0.365	0.875	0.763
Cadmium				
Per doubling of cadmium	1.04 (0.80, 1.35)	1.31 (1.08, 1.58)	1.52 (1.04, 2.23)	0.158
Mercury Quartile (μg/L)				
Q 1 (0.068-0.689)	1 (Reference)	1 (Reference)	1 (Reference)	
Q 2 (0.690-1.033)	1.07 (0.64, 1.80)	1.32 (0.90, 1.95)	0.50 (0.16, 1.50)	
Q 3 (1.035-1.470)	1.30 (0.74, 2.29)	1.64 (1.10, 2.46)	1.07 (0.35, 3.23)	
Q 4 (1.471-6.422)	0.82 (0.42, 1.60)	1.76 (1.14, 2.70)	1.36 (0.46, 3.98)	
P-Trend	0.941	0.009	0.030	0.117

Models were adjusted for age, age^2, sex, education, BMI, cigarette smoke, current diagnosis of hypertension, current diagnosis of diabetes, occupational noise, recreational noise, and firearm noise.

PTA, Pure tone average.

[a] Speech-frequency PTA at 0.5, 1, 2, and 4 kHz.

[b] High-frequency PTA at 3, 4, and 6 kHz.

Table S6. Urinary cotinine-adjusted ORs (95% CIs) of hearing loss (>25dB) by blood cadmium levels at single-pollutant models in adults (n=3,292[a])

		Non-adjustment for cotinine[b]	Adjustment for cotinine[c]
Speech-frequency PTA[d]			
Per doubling of cadmium	757/3292	1.22 (1.01, 1.47)	1.24 (1.03, 1.51)
Cadmium Quartile *(µg/L)*			
Q 1 (0.098-0.710)	99/823	1 (Reference)	1 (Reference)
Q 2 (0.711-1.058)	178/823	1.15 (0.75, 1.76)	1.18 (0.77, 1.80)
Q 3 (1.060-1.500)	218/824	1.26 (0.83, 1.89)	1.28 (0.85, 1.94)
Q 4 (1.501-5.540)	262/822	1.56 (1.00, 2.45)	1.63 (1.02, 2.58)
P-Trend		*0.051*	*0.037*
High-frequency PTA[e]			
Per doubling of cadmium	1406/3292	1.35 (1.13, 1.61)	1.34 (1.11, 1.60)
Cadmium Quartile *(µg/L)*			
Q 1 (0.098-0.710)	200/823	1 (Reference)	1 (Reference)
Q 2 (0.711-1.058)	335/823	1.36 (0.96, 1.95)	1.36 (0.95, 1.94)
Q 3 (1.060-1.500)	414/824	1.54 (1.08, 2.22)	1.53 (1.06, 2.20)
Q 4 (1.501-5.540)	457/822	1.86 (1.25, 2.77)	1.82 (1.21, 2.75)
P-Trend		*0.002*	*0.004*

[a] Data for these analyses (n=3,292) used KNHANES 2010-2011 because urinary cotinine levels were not available in KNHANES 2012.

[b] Adjusted for age, age^2, sex, education, BMI, cigarette smoke, current diagnosis of hypertension, current diagnosis of diabetes, occupational noise, recreational noise, and firearm noise.

[c] Further adjusted for urinary cotinine (creatinine-corrected).

PTA, Pure tone average

[d] Speech-frequency PTA at 0.5, 1, 2, and 4 kHz.

[e] Speech-frequency PTA at 3, 4, and 6 kHz.

Table S7. Fish intake-adjusted ORs (95% CIs) of hearing loss (>25dB) by blood mercury levels at single-pollutant models in adults (n=2,973[a])

		Non-adjustment for fish intake[b]		Adjustment for fish intake[c]	
Speech-frequency PTA[d]					
Per doubling of mercury	657/2973	0.98	(0.83, 1.15)	0.98	(0.84, 1.16)
Mercury Quartile *(μg/L)*					
Q 1 (0.620-2.395)	168/743	1	(Reference)	1	(Reference)
Q 2 (2.397-3.558)	145/744	0.77	(0.49, 1.19)	0.78	(0.50, 1.20)
Q 3 (3.560-5.414)	155/743	0.81	(0.53, 1.24)	0.83	(0.54, 1.26)
Q 4 (5.417-40.901)	189/743	0.80	(0.54, 1.18)	0.81	(0.55, 1.19)
P-Trend		*0.325*		*0.363*	
High-frequency PTA[e]					
Per doubling of mercury	1206/2973	1.00	(0.86, 1.16)	1.02	(0.88, 1.18)
Mercury Quartile *(μg/L)*					
Q 1 (0.620-2.395)	274/743	1	(Reference)	1	(Reference)
Q 2 (2.397-3.558)	261/744	0.81	(0.57, 1.15)	0.84	(0.59, 1.19)
Q 3 (3.560-5.414)	294/743	0.76	(0.54, 1.08)	0.79	(0.55, 1.12)
Q 4 (5.417-40.901)	377/743	0.89	(0.62, 1.28)	0.93	(0.65, 1.34)
P-Trend		*0.533*		*0.687*	

[a] Data for these analyses (n=2,973) used subpopulation that had dietary intake information.
[b] Adjusted for age, age^2, sex, education, BMI, cigarette smoke, current diagnosis of hypertension, current diagnosis of diabetes, occupational noise, recreational noise, and firearm noise.
[c] Further adjusted for daily fish intake.
PTA, Pure tone average.
[d] Speech-frequency PTA at 0.5, 1, 2, and 4 kHz.
[e] High-frequency PTA at 3, 4, and 6 kHz.

Table S8. Cholesterol-adjusted ORs (95% CIs) of hearing loss (>25dB) by levels of blood lead, mercury, and cadmium at single-pollutant models in adults (n=5,187)

Variables	No. hearing loss/ No. participants	Non-adjustment for cholesterol[a]		Adjustment for cholesterol[b]	
Speech-frequency PTA[c]					
Lead					
Per doubling of lead	1124/5187	1.15	(0.94, 1.41)	1.15	(0.94, 1.40)
Lead Quartile (µg/dL)					
Q 1 (0.327-1.593)	170/1296	1	(Reference)	1	(Reference)
Q 2 (1.594-2.146)	204/1296	0.94	(0.65, 1.35)	0.93	(0.65, 1.34)
Q 3 (2.148-2.822)	330/1298	1.29	(0.92, 1.78)	1.28	(0.92, 1.78)
Q 4 (2.823-26.507)	420/1297	1.25	(0.87, 1.79)	1.24	(0.86, 1.78)
P-Trend		*0.066*		*0.071*	
Mercury					
Per doubling of mercury	1124/5187	0.96	(0.84, 1.08)	0.95	(0.84, 1.08)
Mercury Quartile (µg/L)					
Q 1 (0.363-2.378)	284/1296	1	(Reference)	1	(Reference)
Q 2 (2.379-3.528)	250/1297	0.84	(0.61, 1.17)	0.84	(0.61, 1.17)
Q 3 (3.529-5.369)	267/1296	0.79	(0.58, 1.09)	0.79	(0.57, 1.09)
Q 4 (5.370-60.678)	323/1298	0.84	(0.63, 1.12)	0.83	(0.62, 1.11)
P-Trend		*0.221*		*0.210*	
Cadmium					
Per doubling of cadmium	1124/5187	1.18	(1.00, 1.39)	1.18	(0.99, 1.39)
Cadmium Quartile (µg/L)					
Q 1 (0.068-0.689)	140/1293	1	(Reference)	1	(Reference)
Q 2 (0.690-1.033)	255/1300	1.04	(0.73, 1.49)	1.04	(0.73, 1.49)
Q 3 (1.035-1.470)	340/1299	1.22	(0.86, 1.72)	1.22	(0.86, 1.72)
Q 4 (1.471-6.422)	389/1295	1.30	(0.88, 1.91)	1.29	(0.88, 1.91)
P-Trend		*0.117*		*0.120*	
High-frequency PTA[d]					
Lead					
Per doubling of lead	1124/5187	1.30	(1.08, 1.57)	1.30	(1.08, 1.56)
Lead Quartile (µg/dL)					
Q 1 (0.327-1.593)	276/1296	1	(Reference)	1	(Reference)
Q 2 (1.594-2.146)	420/1296	1.13	(0.83, 1.53)	1.13	(0.83, 1.53)
Q 3 (2.148-2.822)	587/1298	1.35	(1.00, 1.81)	1.34	(1.00, 1.80)
Q 4 (2.823-26.507)	810/1297	1.70	(1.25, 2.31)	1.69	(1.24, 2.30)
P-Trend		*<0.001*		*<0.001*	
Mercury					
Per doubling of mercury	1124/5187	0.98	(0.87, 1.09)	0.97	(0.87, 1.09)
Mercury Quartile (µg/L)					
Q 1 (0.363-2.378)	469/1296	1	(Reference)	1	(Reference)
Q 2 (2.379-3.528)	460/1297	0.89	(0.68, 1.16)	0.89	(0.68, 1.16)
Q 3 (3.529-5.369)	524/1296	0.83	(0.63, 1.08)	0.82	(0.63, 1.08)
Q 4 (5.370-60.678)	640/1298	0.89	(0.68, 1.17)	0.89	(0.68, 1.16)
P-Trend		*0.382*		*0.347*	
Cadmium					
Per doubling of cadmium	1124/5187	1.25	(1.08, 1.44)	1.25	(1.08, 1.44)
Cadmium Quartile (µg/L)					
Q 1 (0.068-0.689)	289/1293	1	(Reference)	1	(Reference)
Q 2 (0.690-1.033)	489/1300	1.10	(0.81, 1.49)	1.10	(0.81, 1.49)
Q 3 (1.035-1.470)	645/1299	1.43	(1.06, 1.93)	1.43	(1.06, 1.93)
Q 4 (1.471-6.422)	670/1295	1.47	(1.05, 2.05)	1.47	(1.05, 2.05)
P-Trend		*0.007*		*0.007*	

[a] Adjusted for age, age^2, sex, education, BMI, cigarette smoke, current diagnosis of hypertension, current diagnosis of diabetes, occupational noise, recreational noise, and firearm noise.
[b] Further adjusted for cholesterol.
[c] Speech-frequency PTA at 0.5, 1, 2, and 4 kHz.
[d] High-frequency PTA at 3, 4, and 6 kHz.

Table S9. Education-unadjusted ORs (95% CIs) of hearing loss (>25dB) by levels of blood lead, mercury, and cadmium at single-pollutant models in adults (n=5,187)

Variables	No. hearing loss/ No. participants	Adjustment for education[a]		Non-adjustment for education[b]	
Speech-frequency PTA[c]					
Lead					
Per doubling of lead	1124/5187	1.15	(0.94, 1.41)	1.18	(0.96, 1.44)
Lead Quartile *(µg/dL)*					
Q 1 (0.327-1.593)	170/1296	1	(Reference)	1	(Reference)
Q 2 (1.594-2.146)	204/1296	0.94	(0.65, 1.35)	0.95	(0.66, 1.37)
Q 3 (2.148-2.822)	330/1298	1.29	(0.92, 1.78)	1.31	(0.94, 1.83)
Q 4 (2.823-26.507)	420/1297	1.25	(0.87, 1.79)	1.29	(0.90, 1.86)
P-Trend		*0.066*		*0.040*	
Mercury					
Per doubling of mercury	1124/5187	0.96	(0.84, 1.08)	0.95	(0.84, 1.07)
Mercury Quartile *(µg/L)*					
Q 1 (0.363-2.378)	284/1296	1	(Reference)	1	(Reference)
Q 2 (2.379-3.528)	250/1297	0.84	(0.61, 1.17)	0.83	(0.60, 1.15)
Q 3 (3.529-5.369)	267/1296	0.79	(0.58, 1.09)	0.79	(0.60, 1.08)
Q 4 (5.370-60.678)	323/1298	0.84	(0.63, 1.12)	0.82	(0.61, 1.09)
P-Trend		*0.221*		*0.168*	
Cadmium					
Per doubling of cadmium	1124/5187	1.18	(1.00, 1.39)	1.19	(1.01, 1.41)
Cadmium Quartile *(µg/L)*					
Q 1 (0.068-0.689)	140/1293	1	(Reference)	1	(Reference)
Q 2 (0.690-1.033)	255/1300	1.04	(0.73, 1.49)	1.03	(0.72, 1.48)
Q 3 (1.035-1.470)	340/1299	1.22	(0.86, 1.72)	1.22	(0.87, 1.72)
Q 4 (1.471-6.422)	389/1295	1.30	(0.88, 1.91)	1.33	(0.90, 1.96)
P-Trend		*0.117*		*0.080*	
High-frequency PTA[d]					
Lead					
Per doubling of lead	1124/5187	1.30	(1.08, 1.57)	1.35	(1.12, 1.62)
Lead Quartile *(µg/dL)*					
Q 1 (0.327-1.593)	276/1296	1	(Reference)	1	(Reference)
Q 2 (1.594-2.146)	420/1296	1.13	(0.83, 1.53)	1.15	(0.85, 1.57)
Q 3 (2.148-2.822)	587/1298	1.35	(1.00, 1.81)	1.38	(1.03, 1.85)
Q 4 (2.823-26.507)	810/1297	1.70	(1.25, 2.31)	1.78	(1.31, 2.42)
P-Trend		*<0.001*		*<0.001*	
Mercury					
Per doubling of mercury	1124/5187	0.98	(0.87, 1.09)	0.97	(0.87, 1.08)
Mercury Quartile *(µg/L)*					
Q 1 (0.363-2.378)	469/1296	1	(Reference)	1	(Reference)
Q 2 (2.379-3.528)	460/1297	0.89	(0.68, 1.16)	0.88	(0.68, 1.15)
Q 3 (3.529-5.369)	524/1296	0.83	(0.63, 1.08)	0.83	(0.63, 1.08)
Q 4 (5.370-60.678)	640/1298	0.89	(0.68, 1.17)	0.87	(0.66, 1.13)
P-Trend		*0.382*		*0.273*	
Cadmium					
Per doubling of cadmium	1124/5187	1.25	(1.08, 1.44)	1.28	(1.11, 1.48)
Cadmium Quartile *(µg/L)*					
Q 1 (0.068-0.689)	289/1293	1	(Reference)	1	(Reference)
Q 2 (0.690-1.033)	489/1300	1.10	(0.81, 1.49)	1.11	(0.82, 1.51)
Q 3 (1.035-1.470)	645/1299	1.43	(1.06, 1.93)	1.46	(1.09, 1.97)
Q 4 (1.471-6.422)	670/1295	1.47	(1.05, 2.05)	1.55	(1.12, 2.16)
P-Trend		*0.007*		*0.002*	

[a] Adjusted for age, age^2, sex, education, BMI, cigarette smoke, current diagnosis of hypertension, current diagnosis of diabetes, occupational noise, recreational noise, and firearm noise.
[b] Subtracting adjustment for education.
[c] Speech-frequency PTA at 0.5, 1, 2, and 4 kHz.
[d] High-frequency PTA at 3, 4, and 6 kHz.