

# Perception of Worry of Harm from Air Pollution: Results from the Health Information National Trends Survey (HINTS)

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## Research Article

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# Abstract

Air pollution exposure has been associated with a multitude of diseases and poses a significant concern to public health. For targeted environmental risk communication and interventions to be effective, it is important to correctly identify characteristics associated with worry of harm from air pollution. Using responses from 3,630 participants of the Health Information National Trends Survey 4 Cycle 2, we assessed worry of harm from exposure to indoor (IAP) and outdoor (OAP) air pollution separately. Multinomial logistic regression models were used to calculate odds ratios and 95% confidence intervals. Hispanics were more likely to worry about harm from IAP and OAP compared to non-Hispanic whites. Participants who lived in urban counties were more likely to worry about harm from IAP and OAP compared to those who lived in rural counties. Finally, those who believed their chance of getting cancer was high were more likely to worry about harm from IAP and OAP compared to those who thought their likelihood of getting cancer was low. Worry of harm from IAP and OAP varied across sociodemographic and cancer-related characteristics. Public health professionals should consider these characteristics when developing targeted environmental risk communication and interventions.

## Introduction

Air pollution refers to both man-made and naturally occurring pollutants in the air we breathe. Although air pollution is often invisible and odorless, exposure to it is a ubiquitous and a threat to public health. Air pollutants include, but are not limited to noxious gases, fine particles produced by the burning of fossil fuels, and tobacco smoke. Public health threats due to air pollution include risks of heart and respiratory diseases (El Morabet 2019). In addition, air pollution exposure has been globally linked to some cancers, the most common being lung (Johnson 2011; Fajersztajn et al. 2013; Vermeulen et al. 2019), breast (Schmidt 2018; Shmuel, White, and Sandler 2017), and bladder (Pedersen et al. 2018) cancers. A meta-analysis of 30 cohort studies from 14 countries found that across numerous cancers, exposure to particulate matter (PM) 2.5, PM 10, and nitrogen dioxide was associated with an increase in mortality from all cancers (Kim et al. 2018).

There have been efforts at the policy level to control indoor and outdoor air pollution. Some examples in recent years include the Clean Air Act of 1970 in the United States (US) and World Health Organization interim targets concerning PM control on cardiovascular disease mortality, both of which have led to a decrease in particle pollution and ground-level ozone pollution (Liu et al. 2018; Ross, Chmiel, and Ferkol 2012). Nevertheless, approximately seven million people die from air pollution exposure around the world every year (Joanna, Katherine, and Pallavi 2020). Further, adverse health effects due to air pollution exposure are often concentrated in vulnerable populations including, but not limited to, those who have been characterized as having low socioeconomic status and individuals suffering from pre-existing conditions (O'Neill, Kinney, and Cohen 2008).

Indoor and outdoor air pollution are derived from different sources and pose different health risks; therefore, it is important to distinguish between the two. Outdoor air pollution refers to pollutants found

outside the built environment such as ground-level ozone, noxious gases, and fine particles produced by burning fossil fuels by motor vehicles and power plants. Exposure to chemicals found in air pollution are harmful to humans because these chemicals are often small enough to penetrate deep inside the lungs and cause a variety of adverse reactions such as early impairment of airway function, chronic system inflammation, oxidative stress, and lung cancer(Boulanger et al. 2017; Fajersztajn et al. 2013; Turner et al. 2017).

Indoor air pollution refers to air pollutants found inside our homes, schools, and other building environments. Sources of the most common indoor air pollutants from low-to-middle-income countries (LMIC) often differ from the sources found in developed countries like the US. Indoor air pollutants in the US, are commonly derived from secondhand smoke, carbon monoxide exposure from gas and wood stoves of which use is higher in rural counties than urban counties (Sircar et al. 2015), and radon exposure from building foundations (Seguel et al. 2017). Overall, indoor air pollution remains a major public health concern because people often spend most of their time indoors at work or inside their homes, further exacerbating the concentration of exposure to harmful indoor pollutants.

Effective risk communication and targeted interventions, such as household and behavior change interventions, can be productive tools to mitigate the adverse effects of air pollution exposure. Additionally, it is essential to inform the public about air pollution risk in ways that do not create “undue apathy, complacency, or overconfidence while not creating undue stress or alarm”(Fitzpatrick-Lewis et al. 2010). Nevertheless, due to the variability of an individual’s air pollution exposure and public health risk across the US, developing a one-size-fits-all risk communication strategy along with targeted interventions can be challenging and ineffective. Therefore, “effective risk communication about air quality must provide local and real-time information, tailored to the needs of the audiences in each community”(Ramirez et al. 2019).

Several studies have examined participants’ perception of harm due to air pollution exposure (Egondi et al. 2013; Liu et al. 2016; Muindi et al. 2014). However, to our knowledge, there have been no studies that have explicitly measured one’s worry of harm from indoor and outdoor air pollution exposure. Additionally, no studies regarding air pollution perception were conducted in the U.S. or explored cancer-related characteristics, such as family cancer history and perception of one’s cancer risk (Börner et al. 2015; Li, Folmer, and Xue 2016; Omanga et al. 2014). Lastly, many of these studies were focused on either indoor or outdoor air pollution separately or used the term “air pollution” without distinguishing whether it was indoor or outdoor(Hodgson and Hitchings 2018; Laws et al. 2015; Orru et al. 2018). The purpose of this study was to examine sociodemographic and cancer-related characteristics associated with worry of harm from exposure to indoor air pollution (IAP) and outdoor air pollution (OAP) using data from a nationally representative survey in the US.

## Materials And Methods

The Health Information National Trends Survey (HINTS) is a nationally representative survey supported by the National Cancer Institute that aims to describe cancer-related knowledge, beliefs, attitudes, and behaviors of adults in the US. HINTS uses a probability sample of U.S. telephone numbers to reach a cross-section of the adult, non-institutionalized, and civilian U.S. population. Data were collected using a computer-assisted telephone interview system administered in English or Spanish. Response rates were calculated using the Response Rate 2 (RR2) formula of the American Association of Public Opinion Research (Nelson et al. 2004). We utilized data from the 2012 iteration of the HINTS 4 Cycle 2. There was a total of 3,630 participants in the 2012 iteration of the HINTS with an overall response rate of 40%. Racial and ethnic minorities were oversampled to increase the precision of estimates for minority sub-populations. Additional details on the HINTS methodology as well as access to the complete HINTS datasets can be found on [hints.cancer.gov](https://hints.cancer.gov) as well as previous literature and reports (Blake et al. 2016; Westat 2015).

For this study, we used the questions “How much do you worry that indoor air pollution will harm your health?” and “How much do you worry that outdoor air pollution will harm your health?”. Participants were able to respond: “not at all”, “a little”, “somewhat”, or “a lot” to each question. For indoor and outdoor air pollution, responses to “a little” and “somewhat” were combined to create three categories of responses: “a lot”, “some or a little”, and “not at all”.

Sociodemographic variables included sex (male and female), age (18–34, 35–49, 50–64, and  $\geq 65$ ), race/ethnicity (Hispanic, non-Hispanic white, non-Hispanic black, and Asian, Pacific Islander, other), whether someone was born in the United States, education level (high school diploma or less, some college or post-high school vocational training, bachelor’s degree or more), annual household income ( $\leq \$20,000$ ,  $\$20,000–34,999$ ,  $\$35,000–49,000$ ,  $\$50,000–74,000$ , and  $\geq \$75,000$ ), smoking status (never smoker, former smoker, and current smoker), and whether respondents resided in a rural or urban county. For our analysis, rural and urban residence was determined based on Rural Urban Continuum Codes in which categories 1 through 3 (counties with 250,000 residents or more) were considered “urban” and categories 4 through 9 (counties with less than 250,000 residents) were considered “rural” (Zahnd et al. 2010). In addition to sociodemographic variables, we also examined cancer-related variables including family history of cancer (No, Not Sure, Yes), previous diagnosis of lung disease, which included chronic lung disease, asthma, emphysema, and/or chronic bronchitis (No, Yes), and perceived likelihood of getting cancer (Very Unlikely or Unlikely, Neither Likely or Likely, and Very Likely or Likely).

Bivariate analyses of sociodemographic variables and cancer-related characteristic variables by worry of harm from IAP and OAP were conducted using the Wald chi-squared test. A p-value of less than or equal to 0.05 was used to determine statistical significance. Multinomial logistic regression was used to calculate odds ratios (OR) and 95 % confidence intervals (CI) for the association between sociodemographic and cancer-related variables and worry of harm from IAP and OAP (separately). Participants with any missing values were removed from the logistic regression analysis. All models were adjusted for demographic variables including gender, age, race/ethnicity, education, and rural-urban residence. SAS (version 9.4; Cary, NC) was used to conduct all statistical analyses.

## Results

The distribution of demographic factors for the sample population and the weighted population are presented in Table 1. Among the sample population, a little more than half consisted of women (n = 2,172, 51.4%). Nearly two-thirds (62.7%) of the respondents were non-Hispanic white, while 1,057 (37.6%) had completed some college or post-high school vocational training, and 926 (31.0%) had an annual household income greater than \$75,000. Most respondents (68.5%) reported a known family history of cancer while 20% of respondents (n = 621) believed they had a very likely or likely chance of getting cancer themselves. The prevalence of respondents who had at least some or a little worry of harm for IAP and OAP was 55.2% and 57.0%, respectively. The prevalence of respondents who worried “a lot” about harm from IAP and OAP were 12.7% and 17.3%, respectively.

Table 1  
Sociodemographic and Cancer-Related Variable Summary

CHARACTERISTIC	N*	%**
	(N = 3630)	
Sex		
Male	1390	48.6
Female	2172	51.4
Age		
18–34	529	30.5
35–49	845	26.4
50–64	1168	25.6
65+	970	17.4
Race/Ethnicity		
Non-Hispanic White	2043	62.7
Hispanic	511	15.7
Non-Hispanic Black	496	15.2
Asian, Pacific Islander, and Other	208	6.4
Born in the USA		
Yes	3056	86.6
No	513	14.4
Education		
High School Diploma or Less	1104	33.8
Some College or Post-High School Vocational Training	1057	37.6
College Graduate or Post-Graduate Degree	1380	28.6
Annual Household Income		
Less than \$20,000	740	21.9
\$20,000–34,999	501	14.9
\$35,000–49,999	459	15.5
\$50,000 - \$74,999	524	16.8
More than \$75,000	926	31.0

CHARACTERISTIC	N*	%**
Smoking Status		
Never Smoker	2052	58.6
Former Smoker	939	22.7
Current Smoker	586	18.7
Reside in Metropolitan or Non-Metropolitan County		
Non-Metropolitan County	543	16.3
Metropolitan County	3087	83.7
Previous Family Cancer History		
No/Don't Know	870	28.0
Yes	2412	72.0
Previous Lung Disease Diagnosis***		
No	2994	84.6
Yes	500	15.4
Likelihood of Getting Cancer		
Very Unlikely or Unlikely	992	35.5
Neither Unlikely nor Likely	1371	44.4
Very Likely or Likely	621	20.0
*N is based on the HINTS respondents; may not sum to total due to missing values		
**% is based on the estimated percentage of the U.S. adult population		
***This includes chronic lung disease, asthma, emphysema, and/or chronic bronchitis		

## Bivariate Analyses

Bivariate associations between worry of harm from IAP and OAP with sociodemographic and cancer characteristic variables are presented in Tables 2 and 3, respectively. Worry of harm from IAP was statistically significantly associated with race/ethnicity, education, rural-urban residence, and one's likelihood of getting cancer (Table 2). Worry of harm from OAP was statistically significantly associated with sex, race/ethnicity, whether someone was born in the U.S., education, smoking status, rural-urban residence, previous family history of cancer, previous lung disease diagnosis, and one's likelihood of getting cancer (Table 3).

Table 2  
Bivariate Analysis of Select Characteristics and Worry of Harm from IAP

	<b>Total</b>	<b>A lot</b>	<b>Some or A Little</b>	<b>Not at all</b>	
	N* (%)**	N (%)	N (%)	N (%)	χ <sup>2</sup> -test
<b>Total</b>	3486 (100.0)	441 (12.7)	1924 (55.2)	1121 (32.2)	p- value
<b>Sex</b>					
Male	1344 (48.8)	147 (42.4)	726 (48.0)	471 (52.6)	0.09
Female	2088 (51.2)	286 (57.6)	1168 (52.0)	634 (47.4)	
<b>Age</b>					
18–34	525 (31.1)	55 (31.9)	275 (29.7)	195 (33.3)	0.26
35–49	834 (26.8)	118 (29.4)	477 (27.8)	239 (23.9)	
50–64	1141 (25.8)	147 (24.8)	646 (27.2)	348 (23.6)	
65+	901 (16.4)	107 (14.0)	479 (15.3)	315 (19.1)	
<b>Race/Ethnicity</b>					
Non-Hispanic White	2009 (67.6)	164 (50.3)	1131 (68.0)	714 (73.6)	< 0.0001
Hispanic	481 (14.2)	111 (23.8)	244 (13.7)	126 (11.4)	
Non-Hispanic Black	484 (11.0)	75 (13.0)	257 (10.6)	152 (10.9)	
Asian, Pacific Islander, and Other	204 (7.2)	32 (12.9)	128 (7.7)	44 (4.0)	
<b>Born in the USA</b>					
Yes	2971 (85.5)	295 (65.1)	1658 (85.9)	1018 (92.9)	< 0.0001
No	476 (14.5)	137 (34.9)	245 (14.1)	94 (7.1)	
<b>Education</b>					



	Total	A lot	Some or A Little	Not at all	
High School Diploma or Less	1021 (32.7)	154 (42.6)	542 (31.8)	325 (30.4)	0.03
Some College or Post-High School Vocational Training	1039 (38.1)	148 (36.2)	582 (39.5)	309 (36.4)	
College Graduate or Post-Graduate Degree	1364 (29.2)	124 (21.3)	768 (28.7)	472 (33.1)	
<b>Annual Household Income</b>					
Less than \$20,000	694 (21.5)	131 (26.5)	363 (21.8)	200 (19.1)	0.39
\$20,000–34,999	489 (14.7)	71 (16.5)	283 (15.1)	135 (13.1)	
\$35,000–49,999	451 (15.4)	51 (14.3)	259 (16.6)	141 (13.7)	
\$50,000 - \$74,999	518 (17.1)	51 (15.4)	291 (15.6)	176 (20.3)	
More than \$75,000	918 (31.4)	82 (27.3)	500 (30.9)	336 (33.9)	
<b>Smoking Status</b>					
Never Smoker	1981 (58.8)	267 (65.9)	1109 (59.4)	605 (54.9)	0.20
Former Smoker	907 (22.8)	100 (18.5)	494 (22.7)	313 (24.6)	
Current Smoker	570 (18.4)	71 (15.6)	310 (17.8)	189 (20.5)	
<b>Rural-Urban Residence</b>					
Rural	522 (16.5)	51 (14.6)	288 (14.4)	183 (21.1)	< 0.01
Urban	2964 (83.5)	390 (85.4)	1636 (85.6)	938 (78.9)	
<b>Previous Family Cancer History</b>					
No	835 (26.0)	103 (30.9)	469 (25.4)	263 (25.2)	0.52
Not Sure	231 (7.5)	33 (6.4)	136 (7.1)	62 (8.6)	
Yes	2339 (66.5)	290 (62.7)	1270 (67.5)	779 (66.2)	

	Total	A lot	Some or A Little	Not at all	
<b>Previous lung disease diagnosis***</b>					
Not Diagnosed with Lung Disease	2897 (84.7)	348 (79.6)	1583 (84.2)	966 (87.6)	0.14
Diagnosed with Lung Disease	487 (15.3)	73 (20.4)	290 (15.8)	124 (12.4)	
<b>Likelihood of Getting Cancer</b>					
Very Unlikely or Unlikely	964 (35.6)	126 (42.1)	545 (36.5)	293 (31.5)	< 0.001
Neither Unlikely nor Likely	1348 (45.2)	132 (33.8)	782 (48.0)	434 (44.3)	
Very Likely or Likely	589 (19.3)	84 (24.0)	297 (15.6)	208 (24.2)	
*N is based on the HINTS survey respondents who answered the IAP question in HINTS survey; may not sum to total due to missing values					
**% is based on the estimated % of U.S. adult population					
***This includes chronic lung disease, asthma, emphysema, and/or chronic bronchitis					

Table 3  
Bivariate Analysis of Select Characteristics and Worry of Harm from OAP

	Total	A lot	Some or A Little	Not at all	
	N* (%)**	N (%)	N (%)	N (%)	$\chi^2$ -test
<b>Total</b>	3511 (100.0)	608 (17.3)	1999 (57.0)	904 (27.8)	p- value
<b>Sex</b>					
Male	1355 (48.7)	201 (40.6)	758 (47.6)	396 (55.6)	< 0.01
Female	2101 (51.3)	393 (59.4)	1216 (52.4)	492 (44.4)	
<b>Age</b>					
18–34	526 (31.0)	65 (25.6)	320 (31.4)	141 (33.2)	0.40
35–49	836 (26.8)	151 (30.1)	491 (27.1)	194 (24.3)	
50–64	1144 (25.7)	206 (28.1)	648 (25.8)	290 (24.0)	
65+	914 (16.5)	165 (16.2)	494 (15.6)	255 (18.5)	
<b>Race/Ethnicity</b>					
Non-Hispanic White	2012 (67.6)	234 (47.9)	1202 (69.5)	576 (74.5)	< 0.0001
Hispanic	486 (14.3)	135 (22.0)	257 (14.6)	94 (9.4)	
Non-Hispanic Black	489 (11.0)	110 (13.7)	256 (9.8)	123 (12.1)	
Asian, Pacific Islander, and Other	202 (7.1)	53 (16.4)	113 (6.1)	36 (4.0)	
<b>Born in the USA</b>					
Yes	2988 (85.5)	428 (66.0)	1735 (87.0)	825 (93.4)	< 0.0001
No	482 (14.5)	171 (34.0)	243 (13.0)	68 (6.6)	
<b>Education</b>					

	Total	A lot	Some or A Little	Not at all	
High School Diploma or Less	1041 (33.0)	207 (44.6)	535 (28.2)	299 (36.3)	< 0.001
Some College or Post-High School Vocational Training	1040 (38.0)	181 (31.5)	604 (40.7)	255 (35.9)	
College Graduate or Post-Graduate Degree	1366 (29.0)	203 (23.8)	828 (31.1)	335 (27.8)	
<b>Annual Household Income</b>					
Less than \$20,000	704 (21.7)	165 (27.7)	369 (19.9)	170 (22.1)	0.21
\$20,000–34,999	492 (14.7)	91 (19.4)	289 (13.4)	112 (14.7)	
\$35,000–49,999	453 (15.4)	78 (15.0)	259 (16.4)	116 (13.4)	
\$50,000 - \$74,999	518 (16.9)	62 (12.2)	316 (17.2)	140 (18.9)	
More than \$75,000	917 (31.3)	125 (25.8)	546 (33.0)	246 (30.9)	
<b>Smoking Status</b>					
Never Smoker	1995 (58.6)	371 (66.0)	1147 (59.5)	477 (52.5)	< 0.01
Former Smoker	915 (22.8)	144 (19.9)	532 (23.9)	239 (22.4)	
Current Smoker	573 (18.5)	89 (14.1)	309 (16.6)	175 (25.1)	
<b>Rural-Urban Residence</b>					
Rural	520 (16.4)	64 (12.4)	287 (14.8)	169 (21.9)	< 0.01
Urban	2991 (83.6)	544 (87.6)	1712 (85.2)	735 (78.1)	
<b>Previous Family Cancer History</b>					
No	845 (26.1)	149 (29.5)	465 (23.1)	231 (30.2)	0.02
Not Sure	231 (7.4)	48 (6.7)	131 (6.7)	52 (9.3)	
Yes	2349 (66.5)	392 (63.7)	1356 (70.2)	601 (60.5)	

	Total	A lot	Some or A Little	Not at all	
<b>Previous lung disease diagnosis***</b>					
Not Diagnosed with Lung Disease	2915 (84.5)	462 (75.7)	1675 (86.2)	778 (86.0)	< 0.01
Diagnosed with Lung Disease	491 (15.5)	122 (24.3)	271 (13.8)	98 (14.0)	
<b>Likelihood of Getting Cancer</b>					
Very Unlikely or Unlikely	973 (35.8)	186 (43.8)	573 (37.4)	214 (27.9)	< 0.001
Neither Unlikely nor Likely	1350 (44.8)	185 (33.6)	802 (45.5)	363 (47.6)	
Very Likely or Likely	593 (19.4)	121 (22.6)	295 (16.1)	177 (24.6)	
*N is based on the HINTS survey respondents who answered the OAP question in HINTS survey, may not sum to total due to missing values					
**% is based on the estimated % of U.S. adult population					
***This includes chronic lung disease, asthma, emphysema, and/or chronic bronchitis					

## Multivariable Analyses

The association of worry of harm from IAP and OAP with select sociodemographic and cancer characteristics is presented in Table 4. Asians, Pacific Islanders, and those from other races (OR: 4.74, 95% CI: 1.93–11.67) and Hispanics (OR: 2.44, 95% CI: 1.34–4.43) were more likely to worry “a lot” about harm from IAP compared to non-Hispanic whites. Those who obtained a high school diploma or less were more likely to worry “a lot” about harm from IAP compared to those who were a college graduate or obtained a post-graduate degree (OR: 2.38, 95% CI: 1.39–4.08). Additionally, those who believed they were very likely or likely to get cancer in their lifetime were approximately two times more likely to worry “a lot” about harm from IAP compared to those who believed they were neither unlikely or likely to get cancer in their lifetime (OR: 1.99, 95% CI: 1.20–3.29). Lastly, respondents who were born outside the U.S. were more likely to worry “some or a little” (OR: 1.90, 95% CI: 1.11–2.93) and “a lot” (OR: 5.64, 95% CI: 3.52–9.01) about IAP than respondents who were born in the U.S.

Table 4  
Regression Analysis of IAP and OAP

Characteristic	Indoor Air Pollution				Outdoor Air Pollution			
	Some or a little		A lot		Some or a little		A lot	
	vs.		vs.		vs.		vs.	
	Not at all		Not at all		Not at all		Not at all	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
<b>Gender</b>								
Male	1.00	-	1.00	-	1.00	-	1.00	-
Female	1.18	0.92–1.50	1.54	1.00–2.36	1.37	0.98–1.91	1.98	1.25–3.15
<b>Race/Ethnicity</b>								
Non-Hispanic White	1.00	-	1.00	-	1.00	-	1.00	-
Hispanic	1.18	0.77–1.79	2.50	1.28–4.88	1.65	1.03–2.66	3.40	1.79–6.47
Non-Hispanic Black	0.98	0.70–1.37	1.53	0.92–2.56	0.83	0.51–1.35	1.56	0.89–2.75
Asian, Pacific Islander, and Other	2.31	1.23–4.32	5.24	2.06–13.35	1.77	0.88–3.59	7.63	3.34–17.45
<b>Born in the USA</b>								
Yes	1.00	-	1.00	-	1.00	-	1.00	-
No	1.82	1.10–2.99	5.61	3.39–9.28	1.65	0.93–2.93	4.59	2.66–7.92
<b>Education</b>								
College Graduate or Post-Graduate Degree	1.00	-	1.00	-	1.00	-	1.00	-
High School Diploma or Less	1.39	1.03–1.88	2.46	1.40–4.31	0.77	0.54–1.10	1.63	0.97–2.74
Some College or Post-High School Vocational Training	1.35	0.99–1.84	1.59	0.96–2.64	1.03	0.76–1.41	1.07	0.69–1.65
<b>Rural-Urban Residence</b>								
Rural	1.00	-	1.00	-	1.00	-	1.00	-

	Indoor Air Pollution				Outdoor Air Pollution			
	Some or a little		A lot		Some or a little		A lot	
	vs.		vs.		vs.		vs.	
	Not at all		Not at all		Not at all		Not at all	
Urban	1.66	1.26– 2.19	1.69	0.87– 3.30	1.44	1.02– 2.04	1.73	1.00– 2.98
<b>Previous Family Cancer History</b>								
No	1.00	-	1.00	-	1.00	-	1.00	-
Not Sure	0.88	0.48– 1.60	0.56	0.23– 1.34	1.12	0.60– 2.08	0.83	0.35– 1.96
Yes	1.04	0.76– 1.41	0.85	0.52– 1.38	1.64	1.20– 2.26	1.24	0.76– 2.00
<b>Previous lung disease diagnosis**</b>								
Not Diagnosed with Lung Disease	1.00	-	1.00	-	1.00	-	1.00	-
Diagnosed with Lung Disease	1.27	0.80– 2.03	1.98	1.00– 3.94	0.96	0.58– 1.57	2.16	1.20– 3.86
<b>Likelihood of Getting Cancer</b>								
Neither Unlikely nor Likely	1.00	-	1.00	-	1.00	-	1.00	-
Very Unlikely or Unlikely	0.56	0.42– 0.75	1.01	0.55– 1.88	0.71	0.49– 1.04	1.03	0.60– 1.78
Very Likely or Likely	1.13	0.81– 1.57	1.93	1.15– 3.23	1.51	1.10– 2.08	2.62	1.57– 4.38
*Adjusted for Race, Education, Gender, Age, and Rural-Urban Residence								
**This includes chronic lung disease, asthma, emphysema, and/or chronic bronchitis								

Women were more likely to worry “a lot” about harm from OAP compared to men (OR: 1.95, CI: 1.24–3.08). Asians, Pacific Islanders, and those from other races (OR: 6.25, 95% CI: 2.92–13.36) and Hispanics (OR: 3.02, 95% CI: 1.78–5.15) were more likely to worry “a lot” about harm from OAP compared to non-Hispanic whites. Those who obtained a high school diploma or less were more likely to worry “a lot” about harm from OAP compared to those who obtained a college graduate or post-graduate degree (OR: 1.64, 95% CI: 1.03–2.61). Participants who lived in an urban county were more likely to worry “a lot” about harm from OAP compared to those who live in rural counties (OR: 1.88, 95%CI: 1.08–3.28). Respondents who were born outside the U.S. were approximately 4.60 times more likely than those born in the U.S. to worry about harm from OAP (OR: 4.60, 95%CI: 2.78–7.63). Additionally, those who had a diagnosis of lung disease were more likely to worry “a lot” about harm from OAP compared to those who

did not have a diagnosis of lung disease (OR: 2.10, 95% CI: 1.20–3.68). Finally, those who believed they were very likely or likely to get cancer in their lifetime were approximately 2.5 times more likely to worry “a lot” about harm from OAP compared to those who believed they were neither unlikely or likely to get cancer in their lifetime (OR: 2.56, 95% CI: 1.57–4.19).

## Discussion

Data from the 2012 HINTS suggest that there are several subgroups of the U.S. population that worried more about harm from IAP and OAP compared to others. The subgroups included women, Hispanics, Asians/Pacific Islanders, and other races (in comparison to non-Hispanic Whites), people born outside the United States, those who lived in urban counties (in comparison to those who did not live in rural counties), as well as people who have a previous family cancer history and/or lung disease diagnosis (in comparison to those who do not have a previous family cancer history and/or lung disease diagnosis). Our findings indicate that such groups should be considered when developing air pollution risk communication and intervention strategies. Additionally, our results suggest that more communication regarding the prevalence and risks of indoor air pollution exposure is needed.

The literature suggests that women, especially those with children, were more aware of and concerned about environmental risks (Deguen et al. 2017; Laws et al. 2015). Additionally, research suggests that air pollution is significantly associated with poor reproductive health (Conforti et al. 2018; Gaskins et al. 2019). Therefore, our finding that women were nearly twice as likely as men to be worried “a lot” about outdoor air pollution is consistent with the literature.

Another noteworthy finding in this study was that respondents born outside the U.S. worried a lot about harm from IAP and OAP compared to those born in the U.S. According to 2012 immigration data, the year the HINTS respondents took this survey, over half of U.S. foreign-born residents came from either Mexico (28.2%) or East and South Asia (25.6%). This is consistent with the literature that the vast majority of air pollution perception studies were based in LMICs, namely China (Huang et al. 2017; Liao et al. 2015; Liu et al. 2016; Zhang et al. 2014) and Mexico (Borbet, Gladson, and Cromar 2018; Börner et al. 2015; Calderón-Garcidueñas et al. 2010). Additionally, the Health Effects Institute 2020 State of Global Air Report found that East and South Asia ranked the highest for household indoor air pollution as well as ambient air pollution exposure in the world (Joanna, Katherine, and Pallavi 2020). This finding has been consistent for the past several decades (Cohen et al. 2017). Although Mexico was lower on that list, the prevalence of hazardous air pollutant exposure in Mexico City is increasing, particularly closer to the Mexican border (Carrillo et al. 2018; Quintana et al. 2018). Perceptions of worry being influenced by thoughts of pollution in one’s home country may explain why those not born in the U.S. worried more about harm from air pollution exposure in comparison to those born in the U.S.

Worry of harm from air pollution exposure also varied by geographic area of residence in this study. Although we found no significant differences with region (data not shown), across IAP and OAP, participants who resided in urban counties were more concerned about air pollution exposure. This



finding is consistent with air pollution literature concerning urban areas which suggests that residents in urban areas have significantly more air pollution exposure compared to rural residents (Cesaroni et al. 2013; Martinez et al. 2018; Oltra et al. 2017; Viehmann et al. 2015)

We also observed that people with cancer-related characteristics, such as a family history of cancer, lung disease diagnosis, and having beliefs they will get cancer is another subgroup of participants that worried about harm from air pollution exposure. This finding is consistent with the literature that indicates an association of cancer and lung disease incidence with air pollution exposure (Fajersztajn et al. 2013; Raaschou-Nielsen et al. 2013), as well as cancer survivorship and air pollution exposure (Deng et al. 2017; Turner et al. 2017). Furthermore, this finding suggests that people with cancer-related characteristics see themselves at risk for adverse health outcomes related to air pollution exposure.

The association between some sociodemographic and cancer-related characteristics and air pollution differed for OAP and IAP. Characteristics of respondents that were statistically significant for OAP and not IAP were gender, previous family history of cancer, and having a previous diagnosis of lung disease. A lack of understanding of the nuances that distinguish indoor from outdoor air pollution could potentially explain these observed differences. Much of the public discourse on air pollution focuses on indoor and outdoor air pollution as one entity or only focuses on outdoor air pollution. Consequently, “the health impacts of exposure to indoor air pollution have yet to become a central focus of research, development aid, and policy making”(Burki 2011). This is an important finding because indoor pollution on average poses more serious health risks compared to outdoor pollution (Bruce, Perez-Padilla, and Albalak 2000; Kim et al. 2015). It is important that air pollution risk communication effectively distinguishes differences between indoor and outdoor air pollution, particularly the sources and health risks associated with each category.

## Conclusions

### Strengths and Limitations

To our knowledge, this is the first study to evaluate the association between worry of harm from indoor and outdoor air pollution and sociodemographic and cancer-related variables. Additionally, the environmental questions we used from the 2012 iteration of HINTS have not been previously published. One strength of this study is that HINTS relies on multiple methods to reduce non-response including an initial mailing of the questionnaire, a reminder card, and up to three additional questionnaire mailings. Other strengths include our ability to account for a wide range of related covariates, including important risk factors and potential confounders such as race/ethnicity, metropolitan residence, and education. Nonetheless, there were some limitations to this study, including the cross-sectional study design. Cross-sectional studies limit the ability to evaluate causality and to compare responders with non-responders (Vanderpool and Huang 2010). Additionally, these data were collected in 2012, and the respondents’ perception may have changed with time. Another potential limitation is that the HINTS did not include an explicit definition of indoor and outdoor air pollution. Participants may not fully understand the inherent

differences (in causes and health risks) of both air pollution types. Moreover, single items to measure such key constructs may have lowered reliability and thereby may have diminished the chances of identifying significant relationships (D'Antoni et al. 2017).

## Implications and Future Research

The sociodemographic and cancer-related characteristics identified in this study can be applied to future research with more recent data. Such research can be used to inform environmental agencies as well as local, state, and federal governments regarding targeted communication and encourage various subgroups to take protective actions against air pollution exposure. Additionally, it is important to understand what factors influence adherence to communication tools such as public service announcements, the Air Quality Index, etc. Future research is warranted which includes greater study participation, more detailed questions about indoor and/or outdoor air pollution knowledge, and more information on whether participants live in areas with high levels of air pollution exposure.

## Declarations

**Author Contributions** This study was conducted by a team of researchers with each contributing in a significant way towards the development of the manuscript. SA and HA conceived the study. SA worked on the methodology, data analysis, and writing the original draft. AAG worked on the data validation and assisted with visualization of the tables. GYL, AAG, and GLE worked on the reviewing and editing. GLE supervised the project. All authors have read and agreed to the published version of the manuscript

**Data availability** The data (HINTS 4, Cycle 2) for the current study are available on the Health Information National Trends Survey website [<https://hints.cancer.gov/data/survey-instruments.aspx#H4C2>].

**Ethics approval** Not applicable.

**Consent to participate** Not applicable.

**Consent for publication** Not applicable.

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