



RESEARCH ARTICLE

Public Perceptions of Air Quality in a County in Ohio

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ABSTRACT

Background: Decisions to protect health and well-being are influenced by public perceptions of air quality. To fill a gap in the literature, this descriptive study examined air quality perceptions in northwest Ohio and compared self-reports of air quality with the air quality index (AQI). Additionally, the perceptions of younger, middle-aged, and older participants were compared.

Methods: Survey questions were adapted from 2 previous research studies and distributed online to individuals who resided or worked in Lucas County, Ohio.

Results: The 181 participants were primarily White, female, college graduates with a mean age of 38 years. Most participants perceived the air quality in August 2020 to be unhealthy for sensitive groups or moderate whereas, based on the AQI, 45.2% of the days in August were categorized as good and 54.8% as moderate. Approximately 40% of participants stated that they or their family members had health problems exacerbated by poor air quality. Participants reported they were very likely or likely to stay inside if they knew the air quality was “bad” or “unhealthy.” Although many participants checked the sky, smelled the air, or used a weather app to determine air quality, more older adults relied on television or radio reports while middle-aged adults looked online.

Conclusion: Local agencies may benefit from understanding air quality perceptions, and their relationship to AQI, to support air quality management practices. The public, and particularly vulnerable populations, should be informed about air quality tracking tools and how to alter their behaviors if necessary.

Keywords: Air pollution; Public opinion; Environmental health

INTRODUCTION

A statewide air quality advisory was issued by the Ohio Environmental Protection Agency (OEPA) for the first time on June 7, 2023, as smoke from Canadian wildfires adversely impacted air quality.¹ Then on June 28 and 29, the OEPA issued another statewide air quality advisory as smoke from Canadian wildfires continued. The air quality index (AQI) developed by the national Environmental Protection Agency (EPA) reports daily air quality from 0 to 500 based on values of 5 major pollutants: carbon monoxide, ground-level ozone, nitrogen dioxide, particulate matter (including PM_{2.5} and PM₁₀), and sulfur dioxide, and is broken into 6 levels of health concern ranging from good to hazardous.² In

June, the highest daily AQI in Toledo, Ohio, was 190 and was considered unhealthy.³ The value of 100 generally corresponds to the pollutant's national air quality standard which is the level set by the EPA for protection of public health.⁴

In the United States (US) and world-wide, PM_{2.5} contributes to the largest proportion of adverse health effects related to air pollution.⁵ Air contaminants can result in both acute (eg, coughing and wheezing, shortness of breath and chest discomfort) and chronic (eg, worsening cardiovascular and respiratory diseases, premature mortality) effects on health.^{6,7} There are still acute and chronic health risks even when national air pollution regulations are met.^{8,9} Additionally, vulnerable populations such as older adults or





those with preexisting diseases, such as asthma, may be more at risk.^{6,10,11} For example, a relationship between short-term exposure to PM_{2.5} and an increased risk of hospitalization and death from heart and lung diseases, diabetes, and clots in the large veins of the legs was found in a sample of Medicare beneficiaries.¹⁰ Recent studies have found a relationship between PM_{2.5} and the incidence of dementia.¹²

A few studies in the US have examined public perceptions of air quality, as well as the relationship between these perceptions and the AQI or PM_{2.5} concentrations.¹³⁻¹⁶ Other studies have investigated the public's awareness of the AQI and where air quality alerts were seen or heard.^{17,18} Individuals who lived in areas of high air pollution ranked it as the most serious problem compared to other community issues such as unemployment and crime.¹⁵ Furthermore, awareness of air quality was higher in areas with AQI data available.¹⁴ Air quality was perceived to be worse among females and those with preexisting health conditions.¹³⁻¹⁵ Conversely, air quality was perceived to be better among Latinos and those who exercised regularly.¹³ Blacks were more likely to be concerned about health effects related to air pollution.¹⁶ Television was the most common medium for getting information or alerts.^{13,16-18} Younger age groups, however, more often reported using an app on their mobile phone or device for receiving air quality alerts.¹⁸ For sources of air quality information, older people were more likely to use an app or look online.¹³ While behavior change resulting from air quality is not common, some individuals have reported using visual cues of air pollution to make changes in behavior, such as spending less time outdoors or closing windows.¹⁴

Background

Lucas County in northwest Ohio is bordered to the east by Lake Erie and southeast by the Maumee River. In 2020, the estimated population of Lucas County was 431 279 individuals.¹⁹ The county contains the city of Toledo and its surrounding suburbs and is about 30% farmland and 10% forests.²⁰ In 2020, the private industry sectors with the highest percentage of workers were health care/social assistance (21.8%) and manufacturing (15.0%).²¹

Information from an environmental health assessment implemented by the Toledo-Lucas County Health Department revealed that air quality was an environmental concern for residents in the county.²² Nine focus groups with 93 county residents were led by a trained moderator who facilitated discussion on health issues related to the environment. Residents thought air pollution was uncontrollable because of their exposure to different air pollution sources throughout the county. Many relied on their visual senses to indicate air quality and discussed personal preventive measures they use to combat poor air quality and protect their health. Residents expressed their views on air quality in the county and made decisions about changes in behavior based on their perceptions and health problems they experienced. Finally, residents discussed the various strategies (eg, stricter regulations)

that could be and are being used to improve health and air quality in their communities. This information provided insights into residents' perceptions about air quality in the county and helped guide the design of the quantitative survey for the current study.

As impacts from climate change, including smoke from wildfires, affect air pollution and more Americans experience poor air quality, it is important to understand individuals' perceptions. Perceptions of environmental concerns, including air quality, influence decisions to protect health and well-being. This descriptive study is the first to examine perceptions of individuals in Lucas County, Ohio, related to air quality, sources of air pollution, factors affecting air quality, credible sources of air quality information, and behavior change based on air quality. Individuals' reports of air quality were also compared to the AQI during the same period. This knowledge may assist local agencies or communities with air quality management such as source control or targeted campaigns to increase awareness of the health impacts related to air quality, particularly for vulnerable populations.

METHODS

Design

A cross-sectional survey was conducted in September 2020 in Lucas County, Ohio, to assess public perceptions and concerns about air quality in the prior month. Perceived levels of concern were compared with levels of concern associated with the AQI during August 2020.

Participants

Convenience sampling was used for the study. Eligible participants were those who stated they resided or worked in the county, were at least 18 years of age at the time of the study, and could read and write in English.

Data Sources

Air Quality Perceptions Survey. A survey was adapted from the research studies conducted by Brown et al¹³ and Reames and Bravo¹⁶ and disseminated in September 2020. Some questions used from these studies were revised to improve understandability, readability, and applicability to the Lucas County area. Since ozone is highest in the summer and people spend more time outdoors, the air quality in the county during the prior month of August was rated. Survey questions also included ranking the seriousness of community issues as well as reporting perceived sources of air pollution, the factors affecting "bad" or "unhealthy" air quality, the factors used to determine "good" air quality, what are the credible air quality information sources in the county, and the likelihood of modifying behaviors due to the air quality. The Appendix contains the primary questions in the survey related to air quality and does not include the demographic questions.

Air Quality Data. This study used publicly available AQI data for Lucas County, Ohio, during 2020 (https://aq5.epa.gov/aq5web/aqidata/download_files.html). The AQI provides information about



local air quality, potentially affected groups of people, and steps to reduce air pollution exposure.² The AQI is required to be reported to the public 7 days a week for metropolitan statistical areas (MSAs) with a population greater than 350 000, such as Toledo. The AQI is calculated from measured pollution concentration data for 5 major pollutants (ozone, particulate matter, carbon monoxide, nitrogen dioxide, sulfur dioxide), each with a national ambient air quality standard (NAAQS) established by the EPA to protect public health (TAD). If multiple pollutants are measured, an AQI is calculated for each, and the pollutant with the highest value is the reported AQI for the day.² For Lucas County, the AQI was the maximum value of 2 pollutants, the daily mean PM_{2.5} concentration or ozone, monitored at 5 outdoor sites maintained by the City of Toledo Environmental Services.³ Six established AQI color-code categories correspond to different levels of health concern and include good (0-50), moderate (51-100), unhealthy for sensitive groups (101-150), unhealthy (151-200), very unhealthy (201-300), and hazardous (>300).²

Procedures

Following University of Toledo institutional review board approval (#300479-UT), a cover letter and survey were made available via Qualtrics, an online survey platform. The cover letter was provided to explain the details of the study, and subsequent consent was implied by proceeding to the survey. Participants were primarily recruited via postings with the Qualtrics link on various social media group sites. An email message was also sent by a marketing and communications specialist with access to email addresses at a state university that invited faculty, staff, and students to complete the survey by clicking the link. Additionally, postcards with the Qualtrics link were distributed at libraries and

outdoor venues such as malls and parks. Participants were not compensated for their participation in this study.

Survey data were downloaded from Qualtrics and analyzed in SPSS using descriptive and inferential statistics. Based on previous studies that found age differences, age groups were also compared on air quality information and changes in behavior. Descriptive statistics (ie, median, range) were calculated on the AQI data for August 2020 and the entire year, and the percentage of days in each level of concern were determined.

RESULTS

Demographics

The demographic profile for the participants (n=181) is presented in Table 1. The majority of participants were White (92.3%), female (74.6%), and non-Hispanic or non-Latino (94.5%). Participants' ages ranged from 18 to 86 years, with a mean of 38 years. There were 80 (51.9%) younger, 37 (24.0%) middle-aged, and 37 (24.0%) older individuals.

Air Quality Data

In 2020, 70.6% (250/354) of days in Lucas County were considered good based on the AQI, 27.1% (96/354) were moderate, and 2.3% (8/354) were unhealthy for sensitive groups.³ Over 2020, the maximum AQI was 136 and the median was 42. More specifically, in August 2020, the median AQI was 52 (range of 27-84), with 14 good days (45.2%) and 17 days (54.8%) that were moderate.³

Perceptions of Air Quality

Participants rated the air quality in the past month (ie, August) as good (13.3%), moderate (39.9%), unhealthy for sensitive groups

Table 1. Participants' Demographic Profile

Demographic Variable	n	Percent (%)
Gender	181	
Male	44	24.3
Female	135	74.6
Another	2	1.1
Self-reported race	181	
White	167	92.3
Black/ African American	7	3.9
Asian	2	1.1
Other	4	2.2
Ethnicity	165	
Non-Hispanic or Non-Latino(a)	156	94.5
Hispanic or Latino(a)	7	4.2
Prefer not to answer	2	1.2
Annual household income	180	
Less than \$24 999	31	17.2
\$25 000 to \$49 999	37	20.6
\$50 000 to \$99 999	40	22.3
\$100 000 to \$149 999	37	20.3
\$150 000 or more	23	12.8
Prefer not to answer	12	6.7
Highest level of education	181	
High school	14	7.7
Some college	35	19.3
College	74	40.9
Graduate school	58	32.0



(41.0%), or unhealthy (5.8%). None of the participants thought the air quality in the previous month was very unhealthy or hazardous.

Most of the participants (44.2%) believed air pollution was a somewhat serious problem, while only 3.9% thought that air pollution was a very serious problem in Lucas County. The most frequently reported very serious problems were the opioid crisis (45.9%), crime (33.1%) and obesity (32.6%) (Table 2).

The majority of participants rated their general health as very good (40.6%) or good (32.9%). Almost 40%, however, reported they had health problems that were made worse by poor air quality, and 40% had family members with health problems that were made worse. Asthma and allergies were the most common health problems exacerbated by poor air quality. A significant relationship was found between participants' perception of air quality and whether they reported any health problems made worse by the air quality ($p=0.009$).

Air Quality Impact on Individual Behaviors

Participants reported they were very likely or likely to change their individual behaviors if they knew the air quality was "bad" or "unhealthy" by staying inside with the windows and doors closed (58.4%) and limiting their outdoor activities such as work (52.0%), exercise/sports (49.7%), and hobbies (47.4%). Significant relationships were also found between those participants who stated their health problems were affected by poor air quality and whether they limited their hobbies outside ($p=0.041$) or work outside ($p=0.049$).

Perceptions of Air Pollution Sources

Half of the participants indicated the air quality was "bad" or "unhealthy" if it had a bad smell. The sources participants perceived as contributing somewhat or a lot to air pollution were manufacturing (90.3%), cars and trucks (86.2%), oil refineries (82.2%), construction (68.0%), landfills (63.4%), farms and agriculture (56.3%), and open burning (46.9%).

Air Quality Information

Factors participants used to determine air quality are reported by young, middle, and older age groups in Figure 1. A high percentage

of participants in all age groups reported that they decided whether the air quality was good by going outside and looking at the sky or smelling the air and using a weather app. A larger percentage of older adults checked reports on the TV or radio (78.4%) but less used social media (27.8%) compared to the younger and middle age groups. The middle age group more often reported looking online (78.4%), compared to the younger and older age groups.

Across the 3 age groups, participants believed the most credible sources of air quality information were the EPA, university researchers, and the news media (see Figure 2). The City of Toledo and the Toledo Metropolitan Area Council of Government were perceived as more credible by the younger age group (76.9%; 78.2% respectively) compared to the middle (59.5%; 65.7% respectively) and older age groups (45.7%; 54.3% respectively). Personal social media was considered the least credible source by all age groups.

Changes in Behavior to Reduce Air Pollution

Figure 3 shows the individual behaviors that participants performed to reduce air pollution. The top behavior reported by the younger adults was using a bicycle or walking (69.7%). Middle-aged and older adults did not overfill or 'top off' their gas tank (82.4% and 75.8%, respectively). Additionally, middle-aged adults made fewer driving trips to reduce air pollution (82.4%).

DISCUSSION

Since 1990, concentrations of air pollutants have dropped dramatically across the US, largely due to policies like the Clean Air Act. Specifically, ozone (8-hour) has decreased 22% and PM2.5 (24-hour and annual) has decreased 42%.²³ Although individuals in Lucas County, Ohio, identified that air pollution was not the most serious problem in the area, only 13% stated that the air quality was good. The actual AQI indicated the air was categorized as good for almost half of the days in August of 2020. Like much of the nation, the air quality in Lucas County, Ohio, is typically below concern. Individual decisions to protect health and well-being are influenced by perceptions of air quality, however, which may or may not correspond to AQI values. In the current study, most individuals in Lucas County, Ohio, reported the air quality was unhealthy for sensitive groups or moderate. Only 6% of residents stated that the air quality was unhealthy. Whereas, 20% and 22%

Table 2. Participant Perceptions about the Problems in Lucas County, Ohio

Problems	N	Not at all serious n (%)	A little serious n (%)	Somewhat serious n (%)	Serious n (%)	Very serious n (%)
Car accidents	180	7 (3.9)	46 (25.6)	74 (41.1)	47 (26.1)	6 (3.3)
Unemployment	180	5 (2.8)	23 (12.8)	58 (32.2)	72 (40.0)	22 (12.2)
Crime	181	1 (0.6)	10 (5.5)	40 (22.1)	70 (38.7)	60 (33.1)
Air pollution	181	9 (5.0)	44 (24.3)	80 (44.2)	41 (22.7)	7 (3.9)
Infectious diseases (eg, COVID, HIV)	180	6 (3.3)	26 (14.4)	53 (29.4)	63 (35.0)	32 (17.7)
Opioid crisis	181	1 (0.6)	8 (4.4)	22 (12.2)	67 (37.0)	83 (45.9)
Obesity	181	2 (1.1)	5 (2.8)	42 (23.2)	73 (40.3)	59 (32.6)
Water Quality	181	8 (4.4)	26 (14.4)	49 (27.1)	62 (34.3)	36 (19.9)

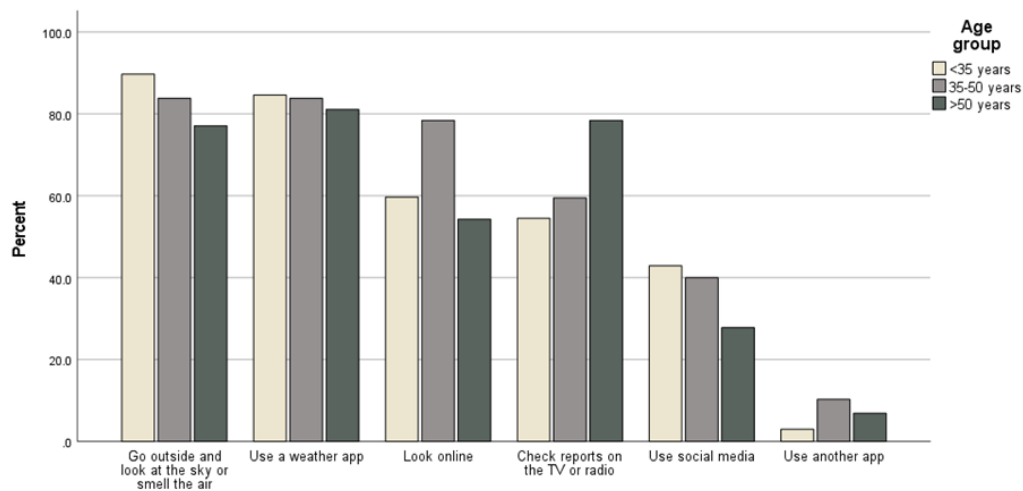


Figure 1. Factors Participants Used to Determine Air Quality

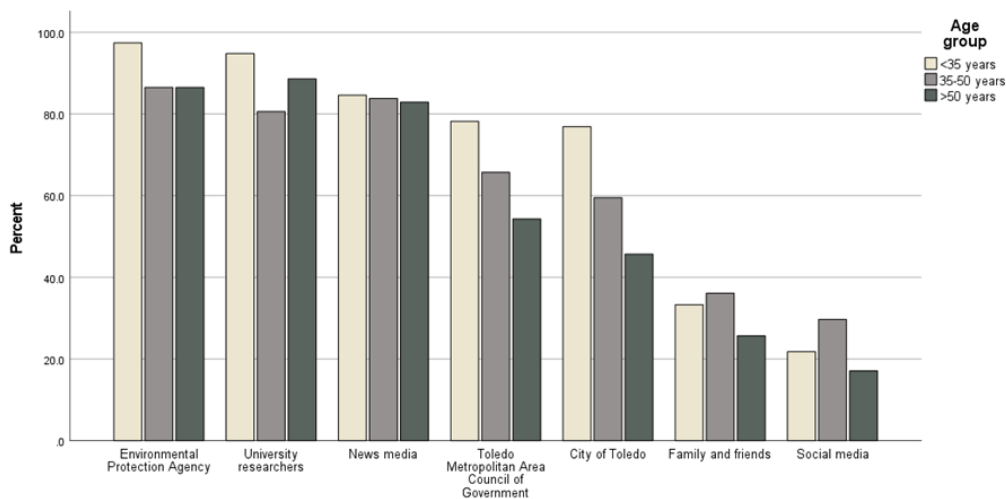


Figure 2. Credible Sources of Air Quality Information

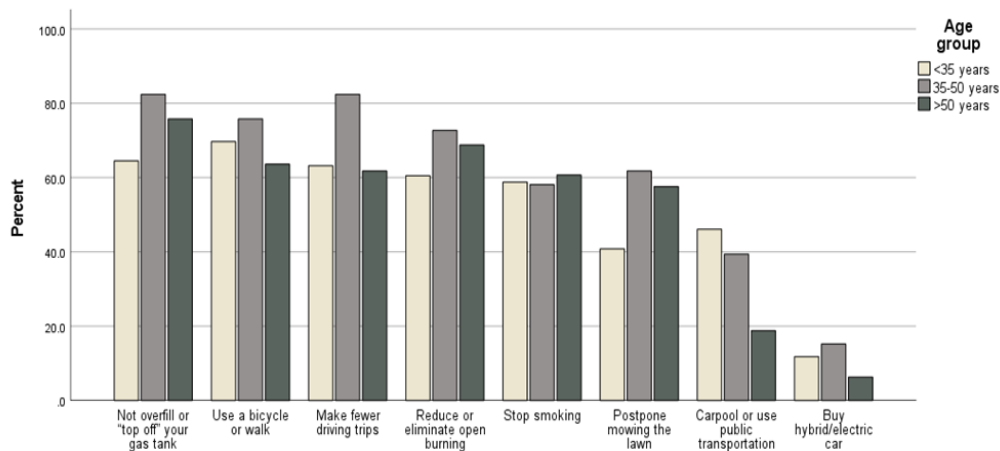


Figure 3. Individual Behaviors to Reduce Air Pollution



of San Joaquin Valley residents in California reported their air quality was unhealthy.^{13,15} One study reported that the majority of their participants (75%) in the San Joaquin Valley were exposed to moderate air quality or medium concentrations of PM_{2.5} (ranged between 12 and 25 $\mu\text{g}/\text{m}^3$).¹⁵ Individuals thought that air pollution was a ‘somewhat serious’ problem in Lucas County, but the opioid crisis, crime, and obesity were the most frequently stated ‘very serious’ problems. Cisneros et al also found that air pollution ranked behind unemployment, crime, and obesity but that those who live in areas of high air pollution ranked it as the most serious problem.¹⁵

The individuals in the current study, of which the majority were female, reported that the air quality was poorer than the AQI. Cisneros et al¹⁵ found that air quality was perceived to be worse among females and Brown et al¹³ stated females were also more likely to check the AQI. Additionally, those with preexisting health conditions perceived the air quality to be poorer.^{13,14} Individuals in Lucas County who had health problems, or reported they had family members with health problems, thought that the air quality made those problems worse.

The main sources of air pollution identified by individuals in the current study were manufacturing, vehicles, and oil refineries. Cisneros et al found that vehicles, windblown dust, and factories were perceived as the main contributors.¹⁵ Visual cues and odor were the primary factors that individuals in Lucas County used to determine the quality of the local air. Weather apps were also frequently used. Similarly, Brown et al found that residents gathered information about air pollution from looking at the sky, checking television reports, seeing the mountains clearly, or smelling the air.¹³ Since PM_{2.5} cannot be seen with the naked eye, it may be one of the reasons there is a difference between air quality perceptions and the AQI.

Air quality alerts on television reach the largest percentage of US adults, although the proportion reporting this channel is decreasing.¹⁶⁻¹⁸ Older adults in the current study checked air quality reports on the television or radio but were less likely to use social media compared to the younger and middle age groups. Tompkins et al found that younger age groups did not report receiving alerts via television but more often report using an app on their mobile phone or device.¹⁸ With regard to sources of air quality information, Brown et al found that older people were less likely to rely on whether they could see the mountains or check the TV or an air quality index.¹³ Individuals across the 3 age groups in the current study thought the most credible sources of air quality information were the EPA, university researchers, and the news media.

While behavior change resulting from air quality is not common, some studies have reported that individuals use visual cues of air pollution to make changes in behavior.¹⁴ On days individuals in Lucas County thought the air quality was “bad,” they played outside less, did less hobbies or work outside, and stayed indoors with the windows and doors closed. Mirabelli et al found that peo-

ple spent less time and did less strenuous activities outside, drove less, and closed their windows if there were more days with alerts of unhealthy air.¹⁴ Brown et al found that females, Latinos, and people of other ethnicities reported avoiding exercising if the air quality was poor.¹³ Some older and middle-aged individuals in Lucas County stated that they did not “top off” the gas tank in their car, while younger individuals used a bicycle or walked.

Despite the knowledge gained from this study, there are limitations. The pandemic restricted the ability to disseminate postcards and paper surveys, so recruitment of participants relied mainly on social media. Social media enables researchers, however, to provide general information about a study to a wider range of individuals who might otherwise be inaccessible to the researchers.²⁴ Additionally, using an online survey may have reduced the number of participants with a lower income or education level and may limit the generalizability of the results. Overall, the air quality of many urban areas improved during the lockdown period of the pandemic, however, the individuals in this study still rated the air quality as worse than the AQI during this time.²⁵⁻²⁷ Whether perceptions are accurate or not, they may change individuals’ behaviors.

PUBLIC HEALTH IMPLICATIONS

Despite air quality that has been steadily improving over the past several decades, recent wildfire smoke has influenced air quality in nearly 75% of states in the US.²⁸ Although impacted by wildfire smoke, the air quality on 73% of the days in June of 2023 in Lucas County, Ohio, was still categorized as good or moderate. If the AQI is unhealthy, however, individuals should reduce their short-term exposure, especially those at greater risk. Long-term behavior changes that individuals can make to reduce air pollution include walking, biking, and taking public transit to reduce vehicle emissions, switching to green power from renewable energy sources, and planting trees to improve air quality. This study’s findings may direct air quality management, such as source control or public health campaigns to increase awareness of community health impacts. Health and government officials can also ensure the public understands the true impacts of poor air quality days in their community and develop appropriate alerts for individuals potentially affected. Future research could examine current perceptions of air quality in Lucas County and whether perceptions in the Midwest have changed as wildfires become more prominent.

Air quality has improved dramatically, but the increasing number of air alert days due to wildfires in the past few years has heightened awareness of air pollution and affected individuals’ behaviors. These descriptive results begin to elucidate the air quality perceptions of individuals who live in Ohio and can be used to guide a larger study. Understanding public perceptions can also assist local and regional health officials in increasing individuals’ comprehension of good and bad air quality days, and subsequently alert individuals if necessary. The findings reveal important opportunities to inform the public about potential health effects of air



pollution, particularly for vulnerable populations, but also to increase awareness of tools (eg, weather apps, AQI website) that the public can use to know the air quality and respond appropriately. The Internet and apps on mobile phones or devices have greatly increased the ability to immediately provide and receive information. Education should be provided to the public on how to use the AQI to guide their outdoor activities and reduce their short-term exposure when the AQI is unhealthy.

CONFLICTS OF INTEREST

The authors declare they have no conflicts of interest.

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Substantial contributions to the conception or design of the work: Ashleigh Konopka, April Ames, Victoria Steiner, Michael Valigosky. Acquisition, analysis, and interpretation of data for the work, drafting the work or revising it critically for important intellectual content, final approval of the version to be published, agreement to be accountable for all aspects of the work: all authors.

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APPENDIX—Air Quality Survey Questions

1. How serious of a problem is each of the following in Lucas County?

	Not at all serious	A little serious	Somewhat serious	Serious	Very serious
Car accidents					
Unemployment					
Crime					
Air pollution					
Infectious diseases (eg, COVID, HIV)					
Opioid crisis					
Obesity					
Algal blooms					

2. How do you decide whether the air quality is good? Do you ... (For each item below, please place an 'X' in the column that relates to your answer).

	Yes	No
Go outside and look at the sky or smell the air		
Check reports on the TV or radio		
Look online		
Use social media (eg, Facebook, Twitter)		
Use a weather app		
Use another app, please specify:		
Other, please specify:		

3. What sources below do you find credible for air quality information?

	Yes	No	Don't know
News media (eg, television, radio, newspaper)			
Family and friends			
Social media (eg, Facebook, Twitter)			
Environmental Protection Agency (EPA)			
Toledo Metropolitan Area Council of Government (TMACOG)			
City of Toledo			
University researchers			
Other, please specify:			

4. Which one of these sources above do you consider to be most credible?

5. In the past month, what has the air quality been like in Lucas County?

Good air quality
Moderately healthy
Unhealthy for sensitive groups
Unhealthy
Very unhealthy
Hazardous

6. How much do each of the following contribute to air pollution in Lucas County?

	Not at all	A little bit	Somewhat	A lot	Don't know
Cars and trucks					
Farms and agriculture					
Landfills					
Manufacturing					
Oil refineries					
Construction					
Open burning					
Other, please specify:					

7. If you know that the air quality is bad or unhealthy, how likely is it that you would ... (For each item below, please place an 'X' in the column that relates to your answer).

	Very unlikely	Unlikely	I'm not sure	Likely	Very likely
Exercise or play sports less outside					
Do less hobbies outside (eg, gardening)					
Work outside less					
Stay inside with windows and doors closed					
Other, please specify:					

8. Would you say that in general your health is

Excellent
Very good
Good
Fair
Poor



9. Do you have any health problems that are made worse by the air quality?
Yes, what are they?
No
10. Do any family members who are living with you have any health problems that are made worse by the air quality?
Yes, which family member(s) and what health problem(s) do they have?
No
11. What activities do you or have you done to reduce air pollution?

	Yes	No
Carpool or use public transportation		
Use a bicycle or walk		
Not overfill or "top off" your gas tank		
Make fewer driving trips		
Postpone mowing the lawn		
Buy hybrid/electric car		
Reduce or eliminate open burning		
Stop smoking (eg, cigarettes, marijuana, etc.)		
Other, please specify:		

12. Is there anything you would like to add? If so, please write it in the space below.