Environmental Science and Pollution Research (2019) 26:24357–24361
https://doi.org/10.1007/s11356-019-05741-7

RESEARCH ARTICLE

The Air Quality Health Index and all emergency department visits

Mieczysław Szyszkowicz[1]

Received: 1 February 2019 / Accepted: 11 June 2019 / Published online: 22 June 2019

Abstract

Through a variety of media formats, the Air Quality Health Index (AQHI) has served as a valuable communication tool for the general Canadian population for several years. This index, calculated and communicated to the public on an hourly basis, is designed to provide important information on the impact of air quality on health. This presentation outlines the association between AQHI values and, for the first time, all-cause emergency department (ED) visits (over one million diagnosed ED visits). It is assumed that a higher AQHI value, reflecting increased health risk, will encourage people to take steps to reduce their exposure, by limiting the duration and intensity of outdoor activity. The case-crossover methodology was used to assess the associations between the considered exposure and ED visits. The results, the estimated odds ratios, are presented as non-linear concentration-response functions. We argue that air health effects, measured as the total number of all-cause ED visits, are related to the values of the AQHI. We postulate that there are differences in this association between males and females, possibly due to gender-specific behavior and/or health conditions.

Keywords Air pollution · Case-crossover · Emergency visits · Health index

Abbreviations

AIC	Akaike information criterion
AQHI	Air Quality Health Index
ED	Emergency department
ICD	International Classification of Diseases
NAPS	National Air Pollution Surveillance
OR	Odds ratio
PM	Particulate matter

Introduction

The Canadian Air Quality Health Index (AQHI) is a risk communication tool designed to help people understand air quality and its relation to their health. More specifically, it is used to inform public health professionals and the general public about the health risks associated with exposure to ambient air pollution. The AQHI, which is a scale whose values range from 1 to 10 and 10+, reflects short-term exposure and provides valuable information that people can use to reduce their exposure and related risk (e.g., adjusting physical exercise routines with respect to location, type, amount, and intensity in accordance with the AQHI values). This health protective tool is carried on The Weather Network and other media and has been well received by the public.

Earlier studies have linked the AQHI to emergency department (ED) visits for specific health conditions such as asthma and ischemic stroke (Szyszkowicz and Kousha 2014; Chen et al. 2014). In this presentation, we contend that this relationship extends to all ED visits for various health conditions, for the first time confirming the value of the AQHI in the context of all-cause ED visits, thereby supporting its on-going use as a valuable health protection communication tool.

The purpose of this study is to investigate the associations between the concentration of ambient air pollutants (measured by the AQHI levels) and health events (measured as ED visits). In addition, this paper is presented and used as a new approach to represent the health risk as a non-linear parametric function of the concentrations.

Responsible editor: Philippe Garrigues

✉ Mieczysław Szyszkowicz
mietek.szyszkowicz@canada.ca

[1] Population Studies Division, Health Canada, 101 Tunney's Pasture Driveway, Ottawa, ON K1A 0K9, Canada

Methods

The strategy involves using the most up-to-date data on air pollutant levels and acute health effects. As health outcomes, we considered all diagnosed emergency department (ED) visits in Edmonton, Canada, for the period of April 18, 1998, to March 31, 2002, covering 1444 days. This specific period was dictated by the availability of the air pollution data obtained from the National Air Pollution Surveillance (NAPS) maintained by Environment and Climate Change Canada. The ED visits were identified using the *International Classification of Diseases*, *9th Revision* (*ICD-9*), with primary discharge diagnoses described by the codes 001 to 999 (Szyszkowicz and Rowe 2016). In total, 1,199,926 ED visits during these 1444 days were identified, and the corresponding data is used in our study. We applied all 18 categories of health problems specified by the ICD-9 codes.

Table 1 shows the frequency of ED visits by the considered ICD-9 disease categories. We do not know precisely which health categories or subcategories are associated with exposure to ambient levels of air pollution. Our assumption is that the majority of ED visits are not related to such exposure. For example, the ED visits classified by ICD-9 codes 140–239. In such cases, we expect that the estimated health risk would be zero, i.e., no association or correlation. The literature shows that some ED visits for various health conditions, even those not expected to be related to air pollution exposure, were indeed associated with such exposure (Szyszkowicz and Rowe 2016). The list of health conditions associated with exposure to ambient air pollution is growing and it is rather difficult to decide a priori, without studies, the correlations for a specific health problem. For a long period of time, only respiratory conditions were considered in the relation with air pollution; later cardiac disease, mortality, mental health, and others were examined.

Table 1 Health problems classified into 18 groups according to ICD-9 codes. Emergency department visits, Edmonton, Canada, April 18, 1998–March 31, 2002

ICD-9	Short description	Visits
001–139	Infectious and parasitic diseases	32,935
140–239	Neoplasms	5194
240–279	Metabolic diseases/immunity disorders	19,862
280–289	Diseases of the blood/blood-forming organs	4448
290–319	Mental disorders	50,233
320–359	Diseases of the nervous system	31,593
360–389	Diseases of the sense organs	45,625
390–459	Diseases of the circulatory system	64,006
460–519	Diseases of the respiratory system	131,878
520–579	Diseases of the digestive system	100,872
580–629	Diseases of the genitourinary system	48,083
630–679	Complications of pregnancy/childbirth	18,278
680–709	Diseases of the skin/subcutaneous tissue	47,440
710–739	Diseases of the musculoskeletal system	57,907
740–759	Congenital anomalies	467
760–779	Conditions originating in the perinatal period	1197
780–799	Symptoms, signs, and ill-defined conditions	133,960
800–999	Injury and poisoning	371,096
001–999	All	1,199,926

In this study, we estimated ambient air pollution exposure using the Air Quality Health Index (AQHI), which is based on three individual ambient air pollutants considered together: ground-level ozone (O3), nitrogen dioxide (NO2), and particulate matter (PM2.5). The index values encapsulate air pollutant concentrations and the health risk estimates based on mortality rates in large Canadian cities (Stieb et al. 2008). The AQHI is calculated using three-hour average concentrations of O3, NO2, and PM2.5 and is reported to the general public on an hourly basis. The AQHI values are calculated according to the following formula:

$$AQHI = \frac{1000}{10.4} \times \left(e^{0.000537 \times O3} + e^{0.000874 \times NO2} + e^{0.000487 \times PM2.5} - 3\right).$$

In this presentation we used continuous values generated by this formula. We used data on hourly levels of the three air pollutants to calculate the AQHI values over the study period of April 18, 1998, to March 31, 2002, for Edmonton, Alberta. We then used the maximum AQHI value observed during each 24-h period to estimate exposure based on a 3-h moving average. We assumed that it is a good representation of the air pollution concentrations, as it is based on a 3-h average and represents the same nature of exposure for both the cases and controls. The following statistics describe the used daily maximum of the AQHI data: minimum 1.5, first quartile 3.4, median 4.2, mean 4.3, standard deviation 1.3, third quartile 5.0, and maximum 10.5.

To investigate the concentration-response associations, we transformed the exposure estimates. Here, we applied the logarithmic function multiplied by the logistic weighting function. Representing the air pollutant concentrations by the variable z, we applied the following formula to estimate the odds ratio (OR) as the function of the variable z, OR(z) = exp.($\beta(z)$). The formula for $\beta(z)$ is as follows:

$$\beta(z) = \beta \times \frac{\log(z)}{1 + \exp\left\{\frac{\mu - z}{r \times \tau}\right\}}$$

where r is the range of the concentrations, and μ (mu) and τ (tau) are the parameters of the logistic function. For given values of the parameters mu and tau, we estimated the coefficient β (Beta). We applied a case-crossover design to realize this model (Maclure 1991). The case-crossover technique controls for all measured and unmeasured time-invariant confounders by design, such as socioeconomic position and comorbidity. In the fitted models, we adjusted weather parameters by representing temperature and relative humidity by natural splines of three degrees of freedom. It has been shown that temperature influences the AQHI (Szyszkowicz 2017a). Many health outcomes are also related to temperature and relative humidity (Szyszkowicz et al. 2015; Szyszkowicz 2017b). The process utilized in this study to fit the model is iterative in nature. It starts with some initial values of the parameters mu and tau. We use the AIC (Akaike information criterion) value to assess the fit of the realized model; accordingly, we adjust for the new values of the parameters mu and tau. This method serves to minimize the AIC value. The details on this technique, including the corresponding software codes, are given in other published research (Szyszkowicz 2018). This more flexible model allows us to observe all forms of concentration-response functions, including the linear function. A similar approach was realized in a series of longitudinal studies related to mortality (Nasari et al. 2016; Burnett et al. 2018).

The Health Research Ethics Board of the University of Alberta approved this main study protocol. The study was conceived and designed after March 31, 2002 (i.e., it is a retrospective study examining data produced between April 1, 1992, and March 31, 2002). These data (since April 18, 1998) are used in the retrospective study related to the AQHI levels and health outcomes.

Results

The results are based on all-cause ED visits and are summarized and presented in Figs. 1 and 2. The figures present the estimated odds ratios (red) and corresponding 95% confidence intervals (blue). Figure 1 shows the concentration-response curves for male patients, with exposure lagged by 0 to 3 days. Positive and statistically significant responses were observed for the considered lags. For same-day exposure (lag 0), the concentration-response function declines above a value of 4.5 for the daily maximum of the AQHI values. It suggests that a high air pollutant concentration does not have an immediate impact.

Figure 2 presents the concentration-response curves for the OR values for ED visits for females. The strongest and non-decreasing associations are observed for exposure lagged by 1 day. The shape of the estimated curve indicates a monotonic, non-decreasing dependency on the AQHI values. The estimated confidence intervals indicate that

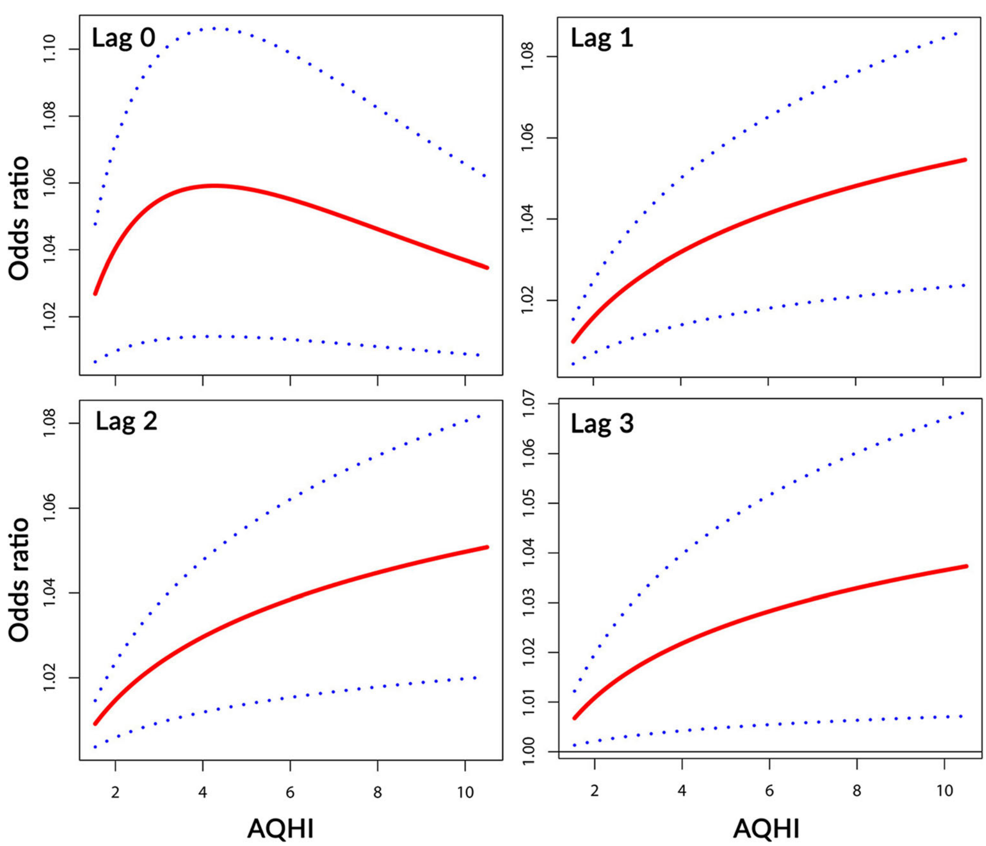

Fig. 1 Concentration-response curves: odds ratios for all-cause ED visits, with exposure as daily maximum of the AQHI values. ED visits for males, Edmonton, Canada, 1998–2002

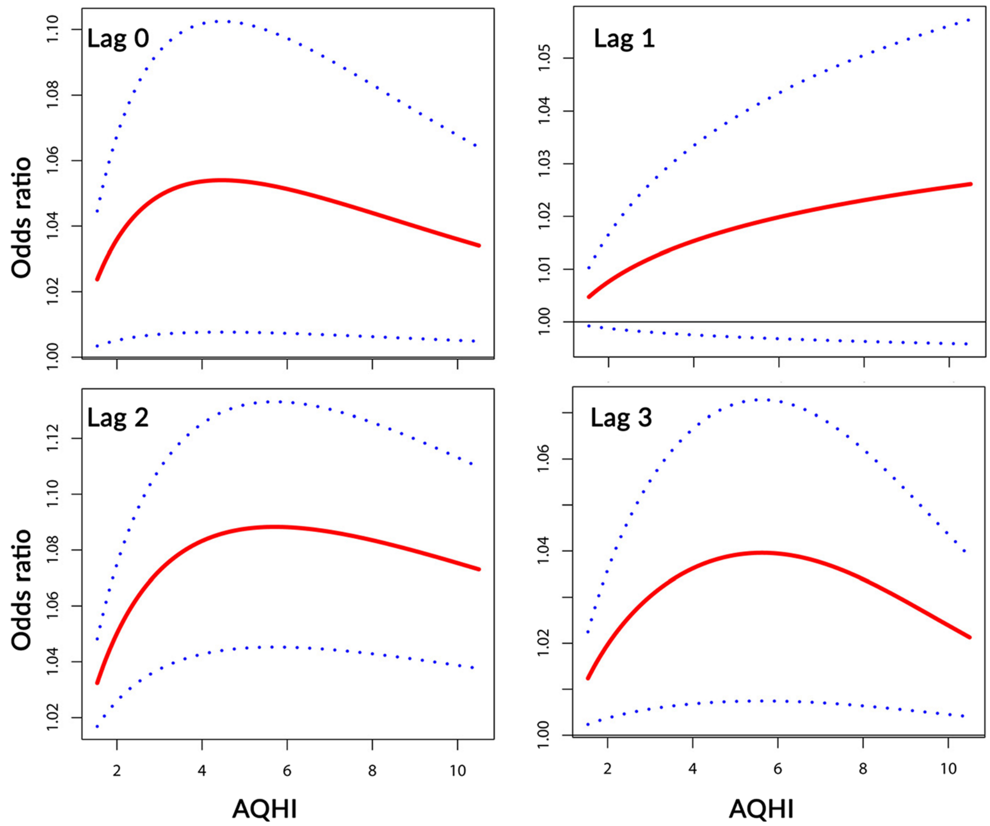

Fig. 2 Concentration-response curves: odds ratios for all-cause ED visits, with exposure as daily maximum of the AQHI values. ED visits for females, Edmonton, Canada, 1998–2002

this association is not statistically significant. For other lags, we see positive associations but they do not become stronger with increasing AQHI values. These results show that female and male populations respond to ambient air pollutant exposure in a different manner, the reason for which warrants further study. It is possible that females and males had ED visits for different diseases and/or react differently to ambient air pollution exposure or they adjust their activities differently.

Discussion

Among the estimated concentration-response functions, we do not observe any indications of the presence of an exposure threshold. One reason may be that we have a combination of three air pollutants and each may have an individual impact, including for various ambient concentrations. For some concentration-response curves, we see decreasing odds ratios for higher AQHI values. High AQHI values are very rare events (even for their daily maximum, the estimated third quartile value is around 5). As a result, very few ED visits occurred at AQHI values above 5, hence resulting in much less statistical power to more precisely estimate the effects. A similar phenomenon was reported in previous research (Szyszkowicz et al. 2015)—i.e., the majority of health events occurring during average conditions (Abelsohn and Stieb 2011; To et al. 2013; Kousha and Valacchi 2015; Szyszkowicz et al. 2015; Kousha and Castner 2016).

The main limitation of this work is to have assigned the same exposure for all the considered cases of ED visits. The estimation of the exposure is based on three monitors in Edmonton with the largest distance among them being 11 km.

Conclusion

Some recently published studies have looked at certain health outcomes (e.g., injuries) that had yet to be analyzed in relation to air pollution exposure, and similarly all-health problems in relation to fine particulate matter (PM2.5) exposure specifically (Ha et al. 2015; Phung et al. 2018). In our AQHI-related research, we observe an association between ED visits and AQHI values (based on 3 ambient air pollutants) even when considering the totality of all-cause ED visits. The earlier exposure (lagged) shows stronger associations than the same day exposure (lag 0). All-cause is a "composite" health outcome—it contains a mixture of health problems associated with exposure and/or not. This implies that the AQHI is a valuable health protection communication tool in the context of all-cause ED visits, while also confirming the findings of previous studies that have associated AQHI values with fewer specific health outcomes.

Acknowledgments The author acknowledges Environment Canada for providing the air pollution data from the National Air Pollution Surveillance (NAPS) network.

Funding information This work was supported by Health Canada.

Compliance with ethical standards

The Health Research Ethics Board of the University of Alberta approved this main study protocol.

References

Abelsohn A, Stieb DM (2011) Health effects of outdoor air pollution: approach to counseling patients using the Air Quality Health Index. Can Fam Physician 57(8):881–887

Burnett R, Chen H, Szyszkowicz M, Fann N, Hubbell B, Pope CA 3rd et al (2018) Global estimates of mortality associated with long-term exposure to outdoor fine particulate matter. Proc Natl Acad Sci U S A 115(38):9592–9597. https://doi.org/10.1073/pnas.1803222115

Chen L, Villeneuve PJ, Rowe BH, Liu L, Stieb DM (2014) The Air Quality Health Index as a predictor of emergency department visits for ischemic stroke in Edmonton, Canada. J Expo Sci Environ Epidemiol 24(4):358–364. https://doi.org/10.1038/jes.2013.82

Ha KH, Cho J, Cho SK, Kim C, Shin DC (2015) Air pollution and unintentional injury deaths in South Korea. Environ Sci Pollut Res Int 22(10):7873–7881. https://doi.org/10.1007/s11356-015-4101-y

Kousha T, Castner J (2016) The Air Quality Health Index and emergency department visits for otitis media. J Nurs Scholarsh 48(2):163–171

Kousha T, Valacchi G (2015) The Air Quality Health Index and emergency department visits for Urticaria in Windsor, Canada. J Toxic Environ Health A 78(8):524–533. https://doi.org/10.1080/15287394.2014.991053

Maclure M (1991) The case-crossover design: a method for studying transient effects on the risk of acute events. Am J Epidemiol 133(2):144–153

Nasari MM, Szyszkowicz M, Chen H, Crouse D, Turner MC, Jerrett M, Pope CA, Hubbell B, Fann N, Cohen A, Gapstur SM, Diver WR, Stieb D, Forouzanfar MH, Kim SY, Olives C, Krewski D, Burnett RT (2016) A class of non-linear exposure-response models suitable for health impact assessment applicable to large cohort studies of ambient air pollution. Air Qual Atmos Health 9(8):961–972

Phung VLH, Ueda K, Kasaoka S, Seposo X, Tasmin S, Yonemochi S et al (2018) Acute effects of ambient PM2.5 on all-cause and cause-specific emergency ambulance dispatches in Japan. Int J Environ Res Public Health 15(2):15. https://doi.org/10.3390/ijerph15020307

Stieb DM, Burnett RT, Smith-Doiron M, Brion O, Shin HH, Economou V (2008) A new multipollutant, no-threshold air quality health index based on short-term associations observed in daily time-series analyses. J Air Waste Manag Assoc 58(3):435–450

Szyszkowicz M (2017a) Ambient temperature and the Air Quality Health Index. J Civil Eng Environ Sci 3(1):006–007. https://doi.org/10.17352/2455-488X.000013

Szyszkowicz M (2017b) Cardiopulmonary mortality and temperature. Environ Pollut Prot 2(1). https://doi.org/10.22606/epp.2017.21005

Szyszkowicz M (2018) Concentration-response functions for short-term exposure and air pollution health effects. Environ Epidemiol J 2: e011. https://doi.org/10.1097/EE9.0000000000000011

Szyszkowicz M, Kousha T (2014) Emergency department visits for asthma in relation to the Air Quality Health Index: a case-crossover study in Windsor, Canada. Can J Public Health 105(5):e336–e341. https://doi.org/10.17269/cjph.105.4539

Szyszkowicz M, Rowe BH (2016) Respiratory health conditions and ambient ozone: a case-crossover study. Insights Chest Dis 1:9 http://insightsinchestdiseases.imedpub.com/respiratory-health-conditions-and-ambient-ozone-a-casecrossover-study.php?aid=8320. Accessed 16 June 2019.

Szyszkowicz M, Porada E, Grafstein E (2015) Ambient air conditions and emergency department visits in Vancouver. Adv Environ Res 3: 109–118 https://www.novapublishers.com/catalog/product_info.php?products_id=56246. Accessed 10 March 2017

To T, Shen S, Atenafu EG, Guan J, McLimont S, Stocks B et al (2013) The air quality health index and asthma morbidity: a population-based study. Environ Health Perspect 121(1):46–52. https://doi.org/10.1289/ehp.1104816