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REVIEW ARTICLE

The association between air pollution and cancers: controversial evidence of a systematic review

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Abstract

There are inconsistent reports on the association between air pollution and cancers. This systematic review was, therefore, conducted to ascertain the relationship between air pollution and some cancers. This is a systematic review study, which all articles published in this area were extracted from January 1, 1950 to December 31, 2018 from Web of Science, PubMed, Scopus, Cochrane Library, MEDLINE, EMBASE, Science Direct, Google scholar. Searching was performed independently by two search-method experts. The required data were extracted from the articles by an author-made questionnaire. Forty-eight articles were investigated. Evidence linking air pollution to some cancers is limited. Leukemia had the highest association with exposure to various air pollutants and bladder cancer had the lowest association. It is noteworthy that the specific type of pollutants in all studies was not specified. Based on the findings, the results are contradictory, and the role of air pollution in some cancers cannot be supported. Accordingly, studies are recommended to be performed at the individual level or multifactorial studies to specifically investigate the relationship between air pollution and these types of cancers. In this way, the role of air pollution in the incidence of these cancers can be determined more accurately.

Keywords Air pollution · Cancer · Systematic review

Introduction

With the industrialization of the countries around the world, air pollution has increased over the recent decades, to such an extent that in some cases, it has threatened the life of human beings (Newby et al. 2015; Pourvakhshoori et al. 2020; Straif et al. 2013). The main factors influencing air pollution include the use of motor vehicles, industrial activities, mining activities, power plants, and the use of fossil fuels. Human beings are exposed to air pollutants at all kinds of places, including home, work, public areas, public transport vehicles, and open air. They can be introduced through breathing, foods, and skin contact, which may ultimately lead to various types of respiratory and cardiac morbidities and cancers (Bazyar et al. 2019; Bräuner et al. 2010; Weng et al. 2008). Investigation of the disease burden resulting from the air pollution in 2016 by the World Health Organization (WHO) showed that 4.2 million fatalities have been recorded due to global air pollution, 262,000 of which have been due to lung cancer (Ha et al. 2017).

Cancer is the second cause of increased disease burden and fatality in the world. Every year, there are many fatalities from cancer worldwide, such that, according to the WHO report from 185 countries, in 2018, 18.1 million new cases of cancer and 9.6 fatalities due to the disease occurred. Most of the cases were related to lung, breast, colorectal, prostate, and gastric cancers. Also, lung and breast cancers were the leading cause of mortality in men and women, respectively (Janitz et al. 2016). According to the World Health Organization (WHO), various factors have contributed to the increase in cancer incidence and its resulting mortality including population

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growth, population aging, development and industrialization of countries, and lifestyle changes (de Smith et al. 2017).

Although genetic and environmental factors play a role in the incidence of cancer, environmental factors play a more important role, such that some references have reported up to 80% of the influence of the environmental factors. The most important environmental factors affecting cancer include exposure to radiation, heavy metals, chemical compounds, contaminated water, infections, and air pollution (Straif et al. 2013). One of the factors that have been taken into consideration in recent years is the role of air pollution in the incidence of cancer. According to the International Agency for Research on Cancer (IARC), and other studies elsewhere (Fiebelkorn and Meredith 2018; Janitz et al. 2017; Raaschou-Nielsen et al. 2016; Straif et al. 2013), the role of air pollution and its compounds including benzene, polycyclic aromatic hydrocarbons (PHAS), asbestosis, radon, formaldehyde, sulfur dioxide, ozone, and carbon monoxide has been proved in the incidence of cancer (Parodi et al. 2015; Winters et al. 2015). According to Nielsen et al.'s review, exposure to air pollution has increased the incidence of cancer in childhood (Farioli et al. 2014). Some studies have also shown that exposure to air pollution increases the fatality resulting from cancer (Gao et al. 2014). Studies have suggested that exposure to air pollution results in oxidative damage to DNA and ultimately cellular damage and cancer (Badaloni et al. 2013). Also, in biological studies, carcinogens that are present in the air pollutants have been extracted from human body tissues. All these indicate the role of air pollution in the incidence of cancer (Bailey et al. 2011).

Worldwide, a large number of cancer cases are reported every year, most of which lead to mortality and morbidity. Air pollution is one of the environmental factors associated with cancers. It has been associated with lung, breast, and stomach cancers; however, there is not enough evidence for the association between air pollutants and some other cancers (Magnani et al. 2016; Mattioli et al. 2014). This systematic review aims at investigating the relationship between air pollution and some cancers not attributable to air pollution. This will help improve our understanding of the role of air pollution in the control of these cancers.

Methods

The present study was conducted as a systematic review of the relationship between air pollution and cancer in the world. In this study, all relevant English articles published from the beginning of 1950 to the end of 2018 were extracted from MEDLINE, EMBASE, Scopus, Web of Science, PubMed, Cochrane Library, Science Direct, and Google Scholar. The searching process was performed via the keywords of "cancer," "neoplasm," "malignancy," "tumor," "carcinoma," and "air pollution," either individually and in combination and using "and" or "or" operators.

By this method, all articles related to air pollution and cancers were gathered, and a list of the summary section of the articles was prepared. Then, the profile of the articles, such as the name of the author and journal, along with the articles full text, was given to two researchers trained in the literature review. Every article was independently analyzed by the two researchers. In case any of the articles were rejected, the researchers mentioned the reason for the rejection. If there was a disagreement on the rejected articles between the researchers, the article was judged by a third person. To evaluate the quality of the articles, the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) checklist was used (Boers et al. 2005). This checklist contained 22 items, and scoring was performed considering the significance of every item and the studied choices. In examining the quality of studies, the minimum acceptable score was 15 (Pedersen et al. 2017). The required data were extracted by a pre-authored checklist which included the location and time of the study, type of cancer, community, and air pollution.

Finally, all English articles on air pollution, in which the word cancer was mentioned and had the required criteria, were included in the study. The exclusion criteria were poor quality studies, those that only discussed air pollution or cancer, interventional studies, case reports, or case series. The primary goal of this study was to ascertain the relationship between all types of cancers and air pollution. After a primary search, we found that there are many cancers with a clear association with air pollution, whereas, for some cancers, this associated has not been well investigated, so the association between air pollution and these cancers was further investigated by the research team in this study. A total of 4982 articles were found which were related to air pollution and cancer, of which 1810 were duplicates, 1551 were irrelevant, and 213 were indistinguishable, and thus were eliminated. After reviewing the abstract section of the articles, 796 of them were eliminated because as they did not include the required information. After reviewing the full text of the articles, 42 of them were eliminated because as they did not include the required information. Finally, 91 articles had the inclusion criteria and were included in the study. Our search yielded 43 articles which contained information related to cancers with a strong association with air pollution, such as lung, breast, and stomach cancers, and 48 articles related to cancers with less evidence of air pollution association. Studies containing information on cancers with an established strong association with air pollution (43 articles) were excluded from the study, and the remaining 48 articles were further investigated for a possible association (Fig. 1).

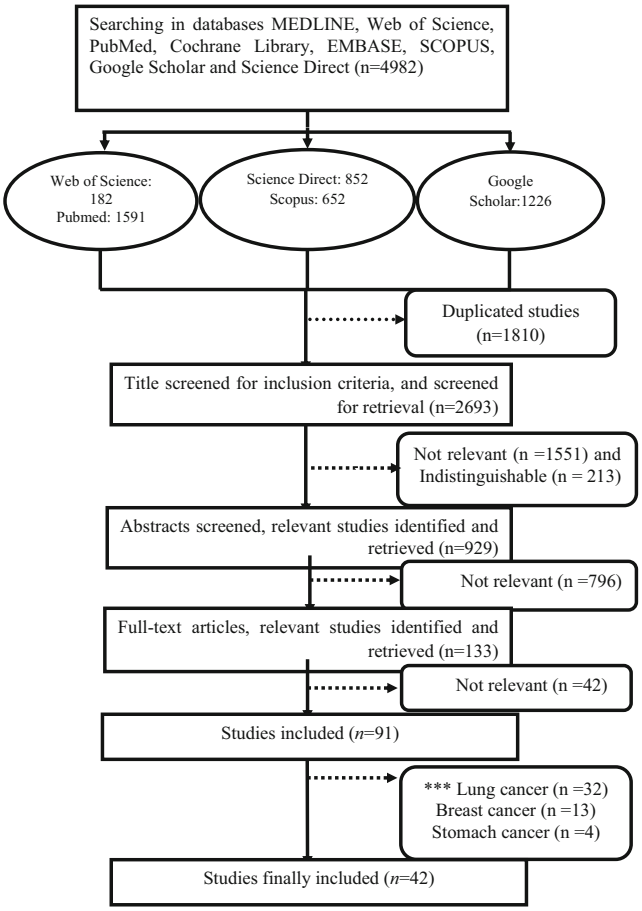

Fig. 1 Results of the systematic literature search. ***Low evidence cancers have been selected

Results

Air pollution and leukemia

Leukemia is one of the most common cancers in childhood and adultness, with 200,000 to 400,000 new cases every year worldwide. The 5-year survival rate of leukemia is low and causes fatality in many patients every year (Bray et al. 2018). The cause of leukemia is currently unknown, although some sources have mentioned genetic and transgenic mutations due to environmental factors (Gao et al. 2014; Lien et al. 2016). Many studies have been conducted in recent years on the role of air pollution and its constituents, including benzene, formaldehyde, and PHA in the incidence of cancer in children and adults. They have found that exposure to air pollution causes leukemia in children and adults (Table 1).

Air pollution and prostate cancer

Prostate cancer is one of the most popular cancers in men afflicting an estimated 60 to 112 cases out of 100,000 men. It causes an annual 310,000 deaths in the world (6). Various factors including family history, smoking, race, diet, physical activity, sexual activity, prostate inflammation, and obesity are related to prostate cancer. Air pollution is one of the factors that has been studied about prostate cancer in recent years (Garcia-Perez et al. 2016) (Table 2).

Air pollution and liver cancer

Liver cancer is the fifth most popular cancer in men and the ninth most popular cancer in women, which causes an annual 746,000 deaths in the world (Pedersen et al. 2017). Hepatocellular carcinoma, alcohol consumption, smoking, and hepatitis B and C are the main causes of liver cancer. Smoke and air pollution include complex compounds such as polycyclic aromatic hydrocarbons, nickel, heterocyclic hydrocarbons, and cadmium that which carcinogenic to humans (Altekruse et al. 2009). Liver cancer is another type of cancer supposed to be affected by air pollution. Few studies have been performed on this subject (Table 2).

Air pollution and bladder cancer

Bladder cancer is the ninth most popular cancer in the world. Smoking, exposure to aniline dyes, employment in rubber and battery industries, and driving vehicles such as busses and trucks are the risk factors associated with bladder cancer (Bray et al. 2018). Exposure to air pollution caused by vehicle exhaust, and combinations such as polycyclic aromatic hydrocarbons and volatile organic compounds, can cause bladder cancer (Cumberbatch et al. 2016) (Table 2).

Air pollution and colorectal cancer

Colorectal cancer is one of the most popular types of cancers among men and women worldwide, with about 1,400,000 new cases per year. Various factors such as obesity, sedentary lifestyle, red meat consumption, and smoking are associated with colorectal cancer (Bray et al. 2018). Air pollution is one of the factors associated with colorectal cancer and has been considered in recent years (Table 3).

Air pollution and mouth cancer

Mouth cancer is one of the most common types of cancer in the world and affects many people per year. This cancer has only a 5-year survival rate and causes a large number of fatalities. Smoking, alcohol, and exposure to tobacco smoke are related to mouth cancer. There have been few studies on exposure to air pollution and mouth cancer worldwide (Table 3).

Table 1 General characteristics of leukemia studied articles that were eligible for the systematic review

Author	Study location	Year of publishing	Type of cancer	Abstract finding
Elvira Vaclavik Brauner (Bräuner et al. 2010)	Denmark	2010	Leukemia	The relative risk for childhood leukemia in association with a 103 Bq/m^3-years increase in radon was 1.77 (1.11, 2.82) among those exposed to high levels of NOx and 1.23 (0.79, 1.91) for those exposed to low levels of NOx (interaction, $P = 0.17$).
Hsu-Huei Weng (Weng et al. 2008)	Taiwan	2008	Leukemia	The results showed that a significant exposure-response connection between exposure to traffic exhaust pollutants and the risk of leukemia in young children after monitoring for probable confounders.
Mina Ha (Ha et al. 2017)	Korea	2017	Leukemia	They resulted that a 10 Bq/m^3 increase in indoor radon concentration was related to a 7% rise in NHL in female children and adolescents in Korea aged less than 20 years.
Amanda E Janitz (Janitz et al. 2017)	USA	2017	Leukemia	The odds of exposure to the fourth quartile of NO2 (11.19–19.89 ppb) were alike in cases compared to controls after modification for maternal education (OR: 1.08, 95% CI: 0.75, 1.55).
Adam J de Smith (de Smith et al. 2017)	USA	2017	Leukemia	Their results recommend that prenatal and early-life tobacco smoke exposure rise the frequency of somatic deletions in children who develop ALL.
Amanda E Janitz (Janitz et al. 2016)	USA	2016	Leukemia	They detected no differences in benzene exposure overall between cases and controls. Nevertheless, after stratified by year of birth, cases born from 2005 to 2010 had a 3-fold increased unadjusted odds of rising exposure compared with controls born in the equal period (4th Quartile OR: 3.53, 95% CI: 1.35, 9.27).
Ole Raaschou-Nielsen (Raaschou-Nielsen et al. 2016)	Denmark	2016	Leukemia	The study indicates an association between long-term exposure to traffic-related air pollution and acute myeloid leukemia in the general population, but not for other subtypes of leukemia.
Stacy Fiebelkorn (Fiebelkorn and Meredith 2018)	UK	2018	Leukemia	The contribution of benzene to smoking-induced leukemia was assessed between 9 and 24% (Upper CL 14–31%).
Nicholas Winters (Winters et al. 2015)	Canada	2015	Leukemia	For chronic lymphocytic leukemia, they found no evidence of relation to air pollution and with all forms of leukemia; they found frail evidence of relation just at low concentrations of NO2.
Stefano Parodi (Parodi et al. 2015)	Italy	2014	Leukemia	Findings recommend a possible etiological role of residential air pollution from industrial places on the risk of emerging leukemia in adult people.
Andrea Farioli (Farioli et al. 2014)	Switzerland	2014	Leukemia	No evidence relating paternal smoking in the conception period or maternal smoking during the pregnancy with ALL was observed.
Yu Gao (Gao et al. 2014)	China	2014	Leukemia	Higher concentrations of NO2 and nearly half of VOCs were detected in the cases than in the controls and were related to the increased risk of childhood AL. The use of synthetic materials for wall decoration and furniture in the bedroom was associated with the risk of childhood AL.
C Badaloni (Badaloni et al. 2013)	Italy	2013	Leukemia	In general, after considering the residence at birth, 35.6% of cases and 42.4% of controls lived along busy roads, and the mean annual PM10 levels were 33.3 (SD = 6.3) and 33.4 mg/m^3 (SD = 6.5).
Helen D Bailey (Bailey et al. 2011)	Australia	2011	Leukemia	They observed no evidence that non-occupational refueling a vehicle with petrol in the year before or during pregnancy enlarged the risk of ALL in the offspring.
Corrado Magnani (Magnani et al. 2016)	Italy	2016	Leukemia	They detected a growth in risk for AnLL, and at a lower degree for ALL, with indicators of exposure to traffic contaminants.
Stefano Mattioli (Mattioli et al. 2014)	Italy	2014	Leukemia	Their results presented frail statistical evidence of a relation of AnLL with maternal exposure to ETS (OR for exposure. 3 h/day = 1.85, 95%CI 0.97–3.52; P trend 0.07). No relation was detected between AnLL and maternal smoking during pregnancy or child exposure to ETS.

As shown in Table 1, the relationship between air pollution and leukemia is controversial. From the above studies, 9 studies reported a positive and significant association between air pollution and Leukemia, whereas, in 7 other studies, no significant relationship was found

Air pollution and brain cancer

Brain cancer has increased in recent years due to industrialization such that its incidence rate in Europe (2012) has risen to 6.6/100.000. Various factors such as ionizing radiation, aging, being Caucasoid, exposure to infectious agents, working in petrochemical and agricultural industries, and exposure to compounds in the polluted air are related to the incidence of this cancer. Some studies have examined the relationship between air pollution and brain cancer (Table 4).

Table 2 General characteristics of the prostate, liver, and bladder cancer studied articles that were eligible for the systematic review

Author	Study location	Year of publishing	Type of cancer	Abstract finding
Marie-Elise Parent (Parent et al. 2013)	Canada	2013	Prostate	Exposure to ambient concentrations of NO2 at the current address was related to an enlarged risk of prostate cancer.
Warren Winkelstein (Winkelstein and Kantor 1969)	New York	1969	Prostate	A relation has been stated between prostatic cancer and suspended particulate air pollution that seems to be independent of economic status, at least in men under 70.
D Boers (Boers et al. 2005)	The Netherlands.	2005	Prostate	No relation was observed for occupational exposure to PAHs (RR 0.75; 95% CI 0.42 to 1.31), diesel exhaust (RR 0.81; 95% CI 0.62 to 1.06), metal dust (RR 1.01; 95% CI 0.72 to 1.40), metal fumes (RR 1.11; 95% CI 0.80 to 1.54), or mineral oil (RR 0.99; 95% CI 0.66 to 1.48) when contrasting the maximum tertile of exposure with no exposure.
Marie Pedersen (Pedersen et al. 2017)	European	2017	Liver	The summary HR related to a 10-μg/m^3 increase in NO2 was 1.10 (95% confidence interval (CI): 0.93, 1.30) and 1.34 (95% CI: 0.76, 2.35) for a 5-μg/m^3 rise in PM2.5.
Luca Cicalese (Cicalese et al. 2017)	Texas	2017	Liver	A relation between the bigger production and consequent exposure to these HAPs and an advanced occurrence of liver cancer in certain counties is recommended.
Huiyu Deng (Deng et al. 2017)	California	2017	Liver	PM2.5 exposures after diagnosis were statistically significantly related to HCC survival. After modification for potential confounders, the all-cause mortality HR related to a 1 standard deviation (5.0 mg/m^3) rise in PM2.5 was 1.18 (95% CI: 1.16–1.20); 1.31 (95% CI:1.26–1.35) for local stage, 1.19 (95% CI:1.14–1.23) for regional stage, and 1.05 (95% CI:1.01–1.10) for distant stage.
Debra Silverman (Silverman et al. 2004)	Spain	2004	Bladder	Living more than 40 years in one city with more than 100,000 population was related to a bigger risk for bladder cancer in general (OR_1.45 (1.01–2.09)) and among never-smokers (OR_1.36 (0.65–2.86)).
Gemma Castano-Vinyals (Castano-Vinyals et al. 2008)	Spain	2008	Bladder	Emissions of polycyclic aromatic hydrocarbons and diesel from industries near the residence, as estimated by specialists, were related to an enlarged risk (OR 1.29, 95% CI 0.85 to 1.98), while lower or no additional risks were detected for other pollution-related variables.
Chi-Kung Ho (Ho et al. 2010)	Taiwan	2009	Bladder	The present study showed that individuals who resided in municipalities with high PSD levels were at an increased risk of death from bladder cancer compared to subjects living in municipalities with a low PSD level; however, the differences are not statistically significant.
Ori Eitan (Eitan et al. 2010)	Israel	2010	Bladder	No significant associations between the SO2-based risk maps and any of the cancers were found.
Shang-Shyue Tsai (Tsai et al. 2009)	Taiwan	2008	Bladder	Subjects who lived in the group of municipalities characterized by the high levels of petrochemical air pollution had a significantly higher risk of death attributed to bladder cancer than subjects in the group that lived in municipalities with the lowest petrochemical air pollution levels, after controlling for possible confounders.
Marie Pedersen (Pedersen et al. 2018)	European	2018	Bladder	The summary HRs related to a 10-mg/m^3 rise in NO2 and 5-mg/m^3 rise in PM2.5 were 0.98 (95% confidence interval [CI] 0.89–1.08) and 0.86 (95% CI 0.63–1.18), respectively.

As presented in Table 2, there is a controversy in the relationship between pollution indicators and prostate, liver, and bladder cancers. Three (3) studies investigated the association between air pollution indicators and prostate cancer. Two (2) studies reported a positive and significant correlation between air pollution and prostate cancer, whereas no significant relationship was found in one study. Out of the 3 studies that investigated the relationship between liver cancers and air pollution, 2 reported a positive and significant correlation between air pollution and liver cancer; however, in the other study, no significant relationship was found. Six (6) studies investigated the association between air pollution and bladder cancer. Four of these studies reported a positive and significant association between air pollution and bladder cancer, whereas, in 2 other studies, no significant relationship was found

Table 3 General characteristics of the colorectal and mouth cancer studied articles that were eligible for the systematic review

Author	Study location	Year of publishing	Type of cancer	Abstract finding
Linda Kachuri (Kachuri et al. 2016)	Canadian	2016	Colorectal	Raised risks were detected among subjects ever exposed to high concentration levels of diesel emissions for colorectal cancer (OR = 1.65, 95% CI = 0.98–2.80) and rectal cancer (OR = 1.98, 95% CI = 1.09–3.60), but not colon cancer.
Verdier (De Verdier et al. 1992)	Sweden	1992	Colorectal	Raised risks of colon cancer among male petrol station/automobile repair workers (RR = 2.3, 0.8–6.6) and males exposed to asbestos (RR = 1.8,0.9–3.6).
Siemiatycki (Siemiatycki et al. 1988)	Canada	1988	Colorectal	Among the relations that have not been subject to previous consideration, the most promising leads for additional examination are the probable relations between gasoline and diesel exhaust and colorectal cancers.
Raymond Fang (Fang et al. 2011)	USA	2011	Colorectal	Excess colon cancer risks were detected in several occupations and industries, particularly those with low physical activity and those including exposure to asbestos, wood dust, engine exhaust and diesel engine emissions, and ammonia.
Mark S Goldberg (Goldberg et al. 2001)	Canada	2001	Colorectal	They have revealed some occupational relations to colon cancer.
Baochang He(He et al. 2016)	China	2016	Mouth	Passive smoking significantly enlarged the risk of oral cancer in Chinese women: adjusted ORs were 2.12 (95% CI¼1.11–4.07).

As indicated in Table 3, there is controversial evidence of the association between colorectal and oral cancer with air pollution indicators. The relationship between air pollution and colorectal cancer is controversial. From the above studies, 4 studies reported a positive and significant association between air pollution and colorectal cancer, whereas, in the other study, no significant relationship was found

Air pollution and cervical cancer

Cervical cancer is the fourth most popular cancer in women with 528,000 new cases per year and 266,000 fatalities. Infection with human papillomavirus, multiple sexual partners, and sexual activity at a young age and multiple pregnancies are risk factors related to cervical cancer (Makuza et al. 2015). Air pollution is one of the other factors which can be related to cervical cancer. This has been investigated in a few studies (Table 4).

After reviewing the articles, the relationship between different pollutants and types of cancers was also examined, as shown in Table 5.

Discussion

Today, cancer claims the second rank among the morbidities in the world, which annually causes millions of fatalities (Bailey et al. 2011). Several risk factors are involved in cancer. One of these risk factors, which has recently been considered by global communities, is the carcinogenic role of air pollution and its compounds, which has been widely studied around the globe (Jerrett et al. 2017). This study reviewed the role of air pollution in the incidence of, blood, prostate, bladder, liver, colorectal, oral, brain, and cervical cancers. The International Agency for Research on Cancer (IARC) has classified outdoor air pollution as a cancer-causing agent (a carcinogen). The IARC is part of the World Health Organization and is one of the primary sources for information on cancer-causing substances for the American Cancer Society and other organizations. In its evaluation, the IARC concluded that outdoor air pollution causes lung cancer and is also linked to an increased risk for bladder cancer (Simon 2013). "The air we breathe is filled with cancer-causing substances," said Kurt Straif, Ph.D., head of the IARC Monographs Section. "Outdoor air pollution is not only a major environmental risk to health in general; it is the most important environmental cancer killer due to the large number of people exposed." The IARC based its report on a review of more than 1000 scientific papers from studies on 5 continents. The studies analyzed the cancer risk caused by various pollutants present in outdoor air pollution, especially particulate matter and transportation-related pollution. The findings came from large epidemiologic studies that included millions of people living in Europe, North and South America, and Asia. "Classifying outdoor air pollution as carcinogenic to humans is an important step," said IARC Director Christopher Wild, PhD. "Given the scale of the exposure, it sends a strong signal that it is vital to implement efficient policies to reduce exposure to pollution worldwide"(Simon 2013). The findings from studies on the relationship between prostate, liver, bladder, colorectal, oral, blood, brain, and cervical cancers, and the air pollution were inconsistent, where there was a significant relationship between air pollution and these cancers, but this relationship was not significant in some cases. Scheurer et al. (2014) in Texas reported that exposure to benzene from air pollution causes uterine dysplasia (Scheurer et al. 2014). Mahalingaiah et al. (2014) studied the relationship between air pollution and the

Table 4 General characteristics of the brain and uterine cancer studied articles that were eligible for the systematic review

Author	Study location	Year of publishing	Type of cancer	Abstract finding
Andersen (Andersen et al. 2018)	European	2018	Brain	Positive, statistically non-significant association between malignant brain tumor and PM2.5 absorbance (hazard ratio and 95% CI: 1.67; 0.89–3.14 per 10–5/m^3), weak positive or null relations to the other pollutants.
Roberta McKean-Cowdin (McKean-Cowdin et al. 2009)	USA	2009	Brain	No raised risk for assessed measures of air pollutants, An unexpected decrease in risk between gaseous air pollutants and brain cancer mortality.
Aslak Harbo Poulsen (Poulsen et al. 2016)	Denmark	2016	Brain	The highest risk for brain cancer was among subjects with the highest exposure levels (80–99 lg/m^3: OR 1.27, 95% CI 0.82–1.96; C100 lg/m^3: 1.40, 95% CI 0.87–2.26 compared with 20 lg/m^3 NOx).
Ole Raaschou-Nielsen (Raaschou-Nielsen et al. 2011)	Denmark	2011	brain and Uterine	NOx at the residence was significantly related to risks for prostate cancer (IRR, 0.97; 95% confidence interval [CI], 0.68; 1.38, per 100 μg/m^3 NOx). Cervical: OR: 2.45, 95% CI: 1.01, 5.93.
Shruthi Mahalingaiah (Mahalingaiah et al. 2016)	USA	2014	Uterine	Living close to a major road and exposures to PM10 or PM10–2.5 were not related to uterine leiomyoma.

As presented in Table 4, there is a controversy in the relationship between pollution indicators and brain and uterine cancers. Four (4) studies investigated the association between air pollution indicators and brain cancer. Two (2) studies reported a positive and significant correlation between air pollution and brain cancer, whereas no significant relationship was found in the other two (2) studies. Out of the 2 studies that investigated the relationship between uterine cancers and air pollution, 1 reported a positive and significant correlation between air pollution and uterine cancer; however, in the other study, no significant relationship was found

risk of Uterine Leiomyomata. They concluded chronic exposure to PM2.5 may be associated with a modestly increased risk of uterine leiomyomata (Mahalingaiah et al. 2014). In a study by Zheng et al. (2013), exposure to $PM_{2.5}$ could incur biological damages to liver tissue and lead to liver cancer (Zheng et al. 2013). Deng et al. (2017) in their study found adverse effects of $PM_{2.5}$ exposure after diagnosis on liver cancer survival. Not only were such effects more profoundly for those diagnosed with early stage, but they also increased strongly with concentration, suggesting that reductions in high $PM_{2.5}$ exposure could increase survival for a no respiratory system cancer (Deng et al. 2017). The hypothesis-generating study of Raaschou-Nielsen et al. (2011) indicates that traffic-related air pollution might increase the risks for cervical and brain cancer. Their results also showed a weak, insignificant association between traffic-related air pollution and bladder cancer. Their results showed no significant relationship between the type of occupation and alcohol consumption as well as smoking and liver cancer (OR: 2.14, 95% CI: 0.96–4.75)(Raaschou-Nielsen et al. 2011). The evidence of an association between ambient air pollution and bladder cancer in the general population is not conclusive (Castaño-Vinyals

Table 5 Relationship between the pollutants studied in articles and types of cancers

Pollutants	Cancers
NO2 (Gao et al. 2014; Janitz et al. 2016; Parent et al. 2013; Pedersen et al. 2017; Raaschou-Nielsen et al. 2016)	Leukemia, prostate cancer, liver cancer
NOx (Raaschou-Nielsen et al. 2011, 2016)	Leukemia, brain cancer
Radon, indoor radon concentration (Bräuner et al. 2010; Ha et al. 2017)	Leukemia
Benzene and hydrocarbons (Bailey et al. 2011; Fiebelkorn and Meredith 2018; Ho et al. 2010)	Leukemia, bladder cancer
Suspected particulate air pollution (Winkelstein and Kantor 1969)	Prostate cancer
PM 10 (Pedersen et al. 2017)	Liver cancer
PM 2.5 (Andersen et al. 2018; Deng et al. 2017; Pedersen et al. 2017)	Liver cancer, brain cancer
Diesel emissions (Kachuri et al. 2016)	Rectal cancer
Asbestos (De Verdier et al. 1992; Fang et al. 2011; Goldberg et al. 2001)	Rectal cancer, colon cancer
Gasoline and diesel exhaust (Siemiatycki et al. 1988)	Colorectal cancer

As shown in the above table, leukemia had the highest association with exposure to various air pollutants and bladder cancer had the lowest association. It is noteworthy that the specific type of pollutants in all studies was not specified and this table is solely specific to the findings of the studies that have identified these types of pollutants

et al. 2008; Liu et al. 2009; Visser et al. 2004). In the study of Visser et al. (2004) in the Netherlands, there was no significant correlation between exposure to air pollution, NOx, traffic density and PAHs, and bladder cancer (Visser et al. 2004). Also, in the study of Fu et al. (2013), exposure to cigarette smoke increased the incidence of colorectal polyps (Fu et al. 2013). In a meta-analysis by Carlos-Wallace et al. (2016), exposure to benzene from air pollution increased the incidence of leukemia in children (Carlos-Wallace et al. 2016). There was an inverse correlation between the amount of benzene in the blood and the number of red blood cells in the study of Koh et al. (2015), where the elevation of the amount of benzene reduced the number of blood cells (Koh et al. 2015). The results of some studies show inconsistencies; for instance, the results from a large prospective study suggest that ambient air pollution was not associated with death from most non-lung cancers, but associations with kidney, bladder, and colorectal cancer death warrant further investigation (Turner et al. 2017).

Conclusions

In general, the lack of evidence of the link between air pollution and these cancers is not due to their low importance because the incidence of cancers is increasing. The lack of studies investigating this relationship can be attributed to the multifactorial nature of these cancers. The majority of studies are likely to address the role of the main cancer risk factors than air pollution, which may be one of the silent risks and/or exacerbating factors of these cancers. Therefore, it is recommended that multifactorial studies measure the different risk factors in the form of regression, and model them to see how much pollution contributes to the epidemiology of these cancers. According to the results of this and other studies on the relationship between air pollution and lung, gastric, and breast cancers, it was observed that exposure to air pollution has an impact on these cancers, but in terms of prostate, bladder, brain, cervical, and liver cancers, the results are contradictory and the role of the air pollution in these types of cancer cannot be determined accurately. Accordingly, it is recommended that studies are performed at the individual level by controlling the confounding factors to more accurately determine the role of air pollution in the incidence of these types of cancer.

However, it is recommended that groups that have direct long-term exposure to air pollution, such as police officers, take measures to reduce their exposure, and have more care than their health. It may be useful for policymakers to implement appropriate strategies toward the reduction of these risks. According to the results, it cannot be stated that exposure to air pollutants increases the incidence of prostate, liver, bladder, colorectal, oral, blood, brain, and cervical cancers. Regarding the relationship between exposure to air pollution and the incidence of these types of cancer, although some studies showed a significant statistical relationship since the source of air pollution is different which may be due to fossil fuels, motor vehicles, mining activities, industries, dust, and smoke, various carcinogens from these sources are brought to the air, each of which has a different effect on the tissues of the body. Other factors such as age, sex, and lifestyle are also related to cancer, so it is recommended that studies are performed at the individual level by controlling the confounding factors and identifying air pollutant carcinogens to accurately determine the role of air pollution in the development of cancer.

Limitations

Only English language articles included.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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