



# Qualitative research about public health risk perceptions on ambient air pollution. A review study

Charlotte Noël<sup>\*</sup>, Christophe Vanroelen, Sylvie Gadeyne

Interface Demography, Vrije Universiteit Brussel, Brussel, Belgium

## ARTICLE INFO

### Keywords:

Literature review  
Qualitative research methods  
Ambient air pollution  
Health risk perceptions  
Environmental epidemiology

## ABSTRACT

**Background:** Understanding public health risk perceptions is essential in efficient environmental health management. In the light of the negative impact of air pollution on health and the direct and indirect mediation of this impact through risk perceptions, it is crucial to better understand the lay perceptions of air pollution. Since qualitative research methods are well suited for this aim, the central objective of this study is to present a review of qualitative research articles in the field of environmental epidemiology that investigate health risk perceptions of ambient air pollution since the 2000s.

**Methods:** We followed the PRISMA-guidelines which resulted in a selection of 20 scientific articles published in peer-reviewed academic journals that used qualitative research methods and reported on health risk perceptions about ambient air pollution.

**Results:** Qualitative research in the field of environmental epidemiology is still scarce. Most of the studies included in the review were based on face-to-face interviews and focus group discussions; a minority used a mixed-method approach. Interesting contributions were made with respect to both the perception of exposure to air pollution and the perception of the health effect associated with air pollution.

**Conclusions:** The review suggests that data generated through qualitative research might complement the traditionally quantitative field of environmental epidemiology. Mixed method multidisciplinary research is likely to provide a more holistic explanation of environmental health patterns observed through quantitative research. These explanations are key in managing environmental health and in developing successful prevention, mitigation and communication strategies. Implementing qualitative research methods contribute to the field of environmental epidemiology as it i) allows for triangulation of findings; ii) generates nuanced findings and new research questions; iii) triggers in-depth understandings of quantitatively identified patterns; iv) leads to additional surprising and/or multifaceted responses; v) enhances relationships between researcher and respondent; vi) increases the awareness of important context-dependent dynamics or interactions that may generate biases and vii) grasps the local, contextual, situational and cultural elements that interact with health risk perceptions.

## 1. Introduction

Environmental epidemiology is concerned with the relation between environmental exposures and human health (Merril, 2008). Environmental health risk assessment and management consist of different steps (hazard identification, dose-response assessment, exposure assessment, risk characterization, risk evaluation, risk perception and communication, control of exposure and risk monitoring) and provides indispensable information for setting preventive action priorities to resolve environmental health problems and can help to monitor and evaluate

the effectiveness of such action (Baker et al., 1999). However, in order to manage environmental health in an effective way and to develop successful prevention and mitigation strategies, it is key to understand public health risk perceptions.<sup>1</sup> Especially when it comes to effective communication about exposures and the effects of this exposures towards affected communities. Risk perceptions are defined as involving 'people's beliefs, attitudes, judgements and feelings, as well as the wider cultural and social dispositions they adopt towards hazards and their benefits' (Pidgeon et al., 1992, p. 89).

In this review we will stress the importance of studying public health

<sup>\*</sup> Corresponding author. Pleinlaan 2, 1050, Brussels, Belgium.

E-mail addresses: [charlotte.noel@vub.be](mailto:charlotte.noel@vub.be) (C. Noël), [christophe.vanroelen@vub.be](mailto:christophe.vanroelen@vub.be) (C. Vanroelen), [sylvie.gadeyne@vub.be](mailto:sylvie.gadeyne@vub.be) (S. Gadeyne).

<sup>1</sup> We will in this article use 'risk perceptions' as a synonym of 'health risk perceptions'.

risk perceptions as an essential step towards efficient environmental health management, focussing on a major environmental health hazard, ambient air pollution. Air pollution is a widespread problem with a huge impact on health and wellbeing, while not being easily sensible and therefore difficult to grasp.

Given the negative health effect of air pollution and the mediation of this effect through risk perception, it is important to better understand lay perceptions related to air pollution. The main objective of this study is therefore to present a review of qualitative studies related to health risk perceptions of ambient air pollution since the 2000s. In our review, we will focus on:

- (1) the different study designs and methodological approaches that have been used;
- (2) the contributions of articles in terms of advancing the evidence in the field

To our knowledge, a peer-reviewed article assessing qualitative research on health risk perceptions of air pollution has not yet been published. We found a few reviews covering two out of the three elements of our focus 1) qualitative research, 2) air pollution and 3) health risk perceptions. In her review on qualitative studies dealing with the relationship between environmental exposures and human health during 1991–2008, [Scammell \(2010\)](#) concluded that qualitative data are insufficiently included in conventional quantitative environmental health research although they have a great potential to improve our understanding of complex exposure pathways, including the influence of social factors on environmental health that would not have been captured using quantitative methods. More concretely, the author states that qualitative data contribute to the understanding of population exposures by providing data on people's behaviours, perceptions of risk, and the social, economic, cultural, and political considerations that influence personal exposure to environmental hazards. In addition, the incorporation of qualitative research methods into environmental health research might have implications for the types of exposures and outcomes typically studied by environmental health scientists (increased focus on stress associated with environmental pollution). [Saksena \(2011\)](#) concluded that few studies address public perceptions of risk associated with urban air pollution and that available studies are rarely conducted by inter-disciplinary teams comprising both social and physical scientists. [Bickerstaff \(2004\)](#) presented findings resulting from recent socio-cultural analyses of air pollution perceptions without focussing however explicitly on qualitative research.

## 2. Methods

This review focusses on articles that focus on 1) qualitative research methods and data (interviews, observations, group discussions, participatory research ...) or mixed method approaches, 2) health risk perceptions and 3) ambient air pollution. Health is defined broadly, referring to physical as well as psychological health. The exposure of interest is ambient air pollution originating from point sources (e.g. industry), line sources (e.g. traffic) and natural (e.g. volcano's) and anthropogenic sources (e.g. traffic) that affect people in their neighbourhoods and communities. Health risk perceptions of air pollution are understood as the perception of the exposure and the health effect – both acute and chronic – of this exposure. Exposure is used to signify the contact that occurs between the human body and the environmental hazard of air pollution. An effect is defined as any change in health status or body function that can be shown to be due to exposure to an environmental hazard ([Baker et al., 1999](#)).

Our review was conducted following the guidelines of the Preferred Reporting Items for Systematic reviews and Meta-Analysis ([Moher et al., 2010](#)). We searched for scientific articles published in peer-reviewed academic journals, excluding other sources of literature such as books and programs or project evaluations. We searched for both English and

French publications published between the 1st of January 2000 and the 31st of December 2020. The search included 14 keywords in total that were related to air pollution ("air pollution", "air quality" or "atmospheric pollution"), methodology ("qualitative research" or "qualitative methodology"), risk perception ("understand\*", "perception\*", "view\*", "attitude\*", "belief\*", "concern\*", "experience\*" or "awareness") and health. These terms resulted in the following key construct: ("air pollution" OR "air quality" OR "atmospheric pollution") AND (qualitative) AND ((understand\* OR perception\* OR view\* OR attitude\* OR belief\* OR concern\* OR experience\* OR awareness) OR (health)) NOT (indoor)). Once established, the key construct was looked for in the title, the keywords or the abstract of the articles. Web of science, Scopus and PubMed were the databases that were initially explored. To ensure we grasped an extensive – not pretending exhaustive – body of relevant articles, we conducted an additional search via Google Scholar.

To select articles for review, two screening criteria were used: 1) the research used qualitative research methods; and 2) the article reported on health risk perceptions of ambient air pollution. Out of 927 articles retrieved from four databases, a screening based on the abstract resulted in a selection of 73 articles for full review. After the text assessment, 20 articles met the eligibility criteria (see Annex 1).

Criteria to exclude articles were that it concerned indoor air pollution instead of outdoor air pollution, that it concerned an expert or stakeholder perspective rather than a lay perspective, that the main focus was too much on policies, communication, citizen science or public understandings of science rather than on risk perceptions, that it finally did not concern qualitative research or that there was no specific focus on air pollution but instead too much on general environmental quality.

No quality appraisal was performed on the reviewed articles. So, independently of the by the authors perceived quality of the 20 articles – which is subjective matter – they were all included in the review.

All 20 articles were categorised in terms of year of publication, source, discipline, place of research, study population, kind of air pollution, health topic(s) and research tools (see [Table 1](#)).

## 3. Theory

There is growing evidence for a negative effect of air pollution on health and well-being. Qualitative studies provide solid evidence of an association between high concentrations of air pollution and mortality ([Rajagopalan et al., 2018](#)) or other health outcomes, such as increased ischaemic heart disease, strokes, infections of the lower respiratory tract, asthma or chronic obstructive pulmonary disease ([Health Effects Institute, 2018](#)) and mental health indicators, such as psychological stress, symptoms of depression or suicide ([Casas et al., 2017](#); [Sass et al., 2017](#)). Furthermore, brain damage caused by air pollution seems to be associated with dementia and with weakened cognitive functioning throughout the life course ([Chen et al., 2017](#); [Clifford et al., 2016](#)). In addition, exposure to air pollutants have potentially harmful effects from the earliest stages of life with negative effects on pregnancies as well as long-term effects that affect susceptibility to disease later in life ([Saenen et al., 2019](#)).

Risk perception plays a crucial role in public response to environmental exposure ([Slovic, 2000](#)). The relationship between environmental exposure (e.g., air pollution) and health (e.g., respiratory effects or chronic stress) is mediated by perceptions of the "exposure" (e.g., air quality) ([Saksena, 2011](#)).

Risk perceptions or more exactly the thereout resulting attitudes towards perceived risks, mediate the potential harmful human health effects of environmental hazards such as air pollution in several ways. [Baldwin et al. \(2020\)](#) state that the formation of an attitude resulting from understanding a risk, results in subsequent behaviour and may impact upon the psychosocial health and wellbeing. A negative attitude may reflect levels of anguish and distress in some people. The most likely mechanism to ill-health effects is through the increase of chronic stress

**Table 1**  
Overview literature.

| Author   | Titel  | Year | Source                                 | Discipline <sup>a</sup>           | Place of research | Kind of air pollution   | Health topic  | Qualitative research instruments   |
|--|--|------|--|-----------------------------------|-------------------|---|---|--|
| Dimitriou, A., & Christidou, V.                          | Pupils' understanding of air pollution   | 2007 | Journal of biological education        | Environmental Education           | Greece            | General   | General health                                      | 132 semi-structured interviews   |
| Becerra, S., Belland, M., Bonnassieux, A., & Liousse, C. | 'Living with' air pollution in Abidjan (Cote d'Ivoire): a study of risk culture and silent suffering in three occupational areas       | 2020 | Health, Risk & Society                 | Sociology of risk and environment | Cote d'Ivoire     | Air pollution resulting from road traffic, wood fires and waste-burning fires | General health                                      | Focus groups (number not specified), 60 semi-structured interviews, key informant interviews (number not specified) and field observations |
| Bickerstaff, K., & Walker, G.                            | Public understandings of air pollution: the localisation' of environmental risk  | 2001 | Global Environmental Change            | Human Geography                   | United Kingdom    | Urban air pollution   | Different (asthma, other respiratory problems, ...) | 50 semi-structured interviews  |
| Bush, J., Moffatt, S., & Dunn, C.                        | Even the birds round here cough': stigma, air pollution and health in Teesside   | 2001 | Health & Place                         | Epidemiology and public health    | United Kingdom    | Industrial air pollution  | Predominantly respiratory                           | 41 semi-structured interviews and 1 focus group  |
| Cisneros, R., Alcalá, E., Schweizer, D., & Burke, N.     | Smoke complaints caused by wildland fire in the southern Sierra Nevada region, California  | 2018 | International Journal of Wildland Fire | Environmental public health       | United States     | Smoke from forest fires   | General health                                      | Review using standard qualitative data analysis procedures of 27 complaints submitted via email, letter or phone                           |
| Day, R.  | Place and the experience of air quality  | 2007 | Health & Place                         | Urban studies                     | United Kingdom    | Air pollution resulting from road traffic                                     | General health                                      | In-depth semi structured interviews with 8 to 12 respondents in each of four study areas   |
| Day, R.  | Traffic-related air pollution and perceived health risk: Lay assessment of an everyday hazard  | 2006 | Health, Risk & Society                 | Urban studies                     | United Kingdom    | Air pollution resulting from road traffic                                     | General health                                      | In-depth semi structured interviews with 10 to 12 respondents in each of four study areas  |
| Atari, D. O., Luginaah, I., & Baxter, J.                 | "This is the mess that we are living in": residents everyday life experiences of living in a stigmatized community                     | 2011 | GeoJournal                             | Health Geography                  | Canada            | Industrial air pollution  | General health                                      | 27 open-ended interviews   |
| Hodgson, A., & Hitchings, R.                             | Urban air pollution perception through the experience of social practices: Talking about breathing with recreational runners in London | 2018 | Health & Place                         | Human Geography                   | United Kingdom    | Urban air pollution   | Breathing   | 14 interviews  |
| Reeve, I., Scott, J., Hine, D. W., & Bhullar, N.         | "This is not a burning issue for me": How citizens justify their use of wood heaters in a city with a severe air pollution problem     | 2013 | Energy Policy                          | Sociology                         | Australia         | PM from wood heaters  | General health                                      | 6 focus groups   |
| Xu, J., Chi, C. S. F., & Zhu, K.                         | Concern or apathy: the attitude of the public toward urban air pollution   | 2017 | Journal of Riks Research               | Environmental Management          | China             | Urban air pollution   | General health                                      | 43 semi-structured in-depth interviews   |
| Li, X., & Tilt, B.                                       | Perceptions of Quality of Life and Pollution among China's Urban Middle Class: The Case of Smog in Tangshan                            | 2017 | The China Quarterly                    | Cultural Anthropology             | China             | Smog  | General health                                      | 30 semi-structured interviews and observations   |
| Longo, B.M.  | The Kilauea Volcano Adult Health Study   | 2009 | Nursing Research                       | Environmental health              | United States     | PM and SO2 resulting from an erupting volcano                                 | Respiratory problems                                | 16 unstructured interviews with open-ended questions   |
| Kondo, M.C., Gross-Davis, C.A., May, K., Davis, L.O.,    | Place-based stressors associated with industry and air pollution   | 2014 | Health & Place                         | Health and Epidemiology           | United States     | Chemical releases from a refinery   | Psychosocial and community stress                   | 8 focus groups   |

(continued on next page)

Table 1 (continued)

| Author   | Titel   | Year | Source                          | Discipline <sup>a</sup>        | Place of research | Kind of air pollution   | Health topic   | Qualitative research instruments                         |
|--|---|------|---------------------------------|--------------------------------|-------------------|---|----------------|--|
| Johnson, T., Mallard, M., Gabbadon, A., Sherrod, C., and Branas, C.C.                                  |   |      |                                 |                                |                   |   |                |  |
| Moffatt, S., & Pless-Mulloli, T.   | "It wasn't the plague we expected." Parents' perceptions of the health and environmental impact of opencast coal mining   | 2003 | Social Science & Medicine       | Environmental epidemiology     | United Kingdom    | Dust from opencast coal mining                                | Asthma         | 31 in-depth, semi-structured interviews                  |
| Muindi, K., Egondi, T., Kimani-Murage, E., Rocklov, J., & Ng, N.                                       | "We are used to this": a qualitative assessment of the perceptions of and attitudes towards air pollution amongst slum residents in Nairobi                                   | 2014 | BMC Public Health               | Epidemiology and Public health | Kenya             | Air pollution arising from industry and dump sites            | General health | 8 focus groups   |
| Ngo, N. S., Kokoyo, S., & Klopp, J.  | Why Participation Matters for Air Quality Studies: Risk Perceptions, Understandings of Air Pollution and Mobilization in a Poor Neighbourhood in Nairobi, Kenya               | 2017 | Public Health                   | Sustainable development        | Kenya             | General   | General health | 4 focus groups and 40 interviews (with same respondents) |
| Ramaswami, A., Baidwan, N. K., & Nagpure, A. S   | Exploring social and infrastructural factors affecting open burning of municipal solid waste (MSW) in Indian cities: A comparative case study of three neighborhoods of Delhi | 2016 | Waste Management & Research     | Environmental engineering      | India             | Particulate pollution from open municipal solid waste-burning | General health | 115 open-ended interviews                                |
| Wakefield, S. E. L., Elliott, S. J., Cole, D. C., & Eyles, J. D.                                       | Environmental risk and (re)action: air quality, health, and civic involvement in an urban industrial neighbourhood  | 2001 | Health & Place                  | Geography                      | Canada            | Air pollution from industry and transport                     | General health | 21 semi-structured in-depth interviews                   |
| Spencer-Hwang, R., Montgomery, S., Dougherty, M., Valladares, J., Rangel, S., Gleason, P., & Soret, S. | Experiences of a Rail Yard Community: Life Is Hard  | 2014 | Journal of Environmental Health | Public Health                  | United States     | Dust originating from rail transport                          | General health | 5 focus groups and 12 semi-structured interviews         |

<sup>a</sup> Disciplines were derived from the first author's online profile. When this information was not found, disciplines were derived from the author's affiliation at the time of publication.

and distress associated with a perceived lack of control over the situation and through the insight that one is being exposed to an unhealthy environment (Baldwin et al., 2020; Lima, 2004). High risk perceptions might thus constitute a cognitive antecedent of a stress reaction negatively impacting upon mental health.

On the other hand, when risks are underestimated, people might not take appropriate measures to protect themselves which impacts on their physical health.

Attitudes resulting from risk perceptions also mediate the potentially harmful human health effects of air pollution in a more indirect way since they might result in behavioural changes and support measures aiming to decrease air pollution thereby mitigating air pollution and its negative health impact. Public awareness and realistic perceptions of the health risks associated with air pollution are therefore key in improving public health and in creating public support for policy measures aimed at reducing air pollution.

Literature mentions a 'perception gap', i.e. a discrepancy between lay public's perceptions and knowledge of environmental risks and the perceptions/knowledge of scientific/policy experts. Expert knowledge is understood as 'objective' knowledge resulting from scientific, often lab/clinical/statistical research based on abstract facts, whereas lay knowledge is understood as 'subjective' knowledge not necessarily grounded

in or validated by scientific research. This 'perception gap' has been a main concern among those responsible for the management of environmental risks and triggered research to identify the reasons behind these differential perceptions (Bickerstaff, 2004).

Applied to the topic of air pollution, it is clear that air pollution has an ontologically objective existence, but the way in which people come to know and make sense of air pollution is socially mediated (Bickerstaff & Walker, 2003). For example, from an expert point of view, a specific place might be perceived as heavily polluted while from a lay perspective, this place may feel free of pollution or less polluted (Bush et al., 2001). Or contrarily, a place that from a lay perspective is polluted and entailing health risks, can be perceived by experts as a place that is not polluted. Bush et al. (2001), studied public understandings of air pollution in Teesside, a heavily industrialized area in England, and observed a perception gap between objective scientific evidence for relatively clean air, and the public opinion related to air quality. In this case lay concerns surrounding air quality have been dismissed as 'wrong' and public authorities stated, "our biggest air quality problem on Teesside is one of perception".

The importance of lay perceptions in the process of policy making is increasingly acknowledged. With respect to environmental risks, Wynne (1992) argues that local knowledge is of instrumental value in risk

assessment, precisely because it holds information that scientific models overlook. Day (2006) claims that the willingness to adopt a more open attitude towards lay-knowledge, may afford productive opportunities for lay communities and experts to work in dialogue in order to understand environmental health risks. Muindi et al. (2014) underline the importance of understanding public perceptions and associated risks to ensure a consultative process in policymaking as opposed to the existing top-down approach where the public is largely a recipient of policy actions without giving any input in their formulation.

Most studies on environmental risk perceptions in general and on air pollution in particular are based on quantitative research methods (Saksena, 2011), dominated by data collection techniques such as surveys and opinion polls. These approaches provide little understanding and fail to explore the factors behind variations in risk perceptions between places and social groups. The main reason is the assumption that air pollution risks exists 'out there', independently of society, history or culture attitudes (Bickerstaff & Walker, 2003). Obviously, there is need for more qualitative approaches alongside the recognition of the political and cultural impact on perceptions and the inconsistencies in how people act and think upon perceptions (Saksena, 2011). Perceptions of and responses to risks and hazards are multi-dimensional and influenced by complex social, political and cultural processes, (Brown, 2003). Qualitative research will lead to a better understanding of the 'why' of quantitatively identified differences in perceptions (Brooks et al., 2010) and offer opportunities to better understand public health risk perceptions in general and public health risk perceptions of air pollution in particular.

Yet, most studies continue to report quantitative, descriptive findings that provide a rather superficial view of the processes underlying perception and fail to focus on the social dimension of air pollution (Bickerstaff & Walker, 2001). In addition, Scammell's (2010) review on qualitative environmental health research indicated that qualitative data, if available, are published to a limited extent in traditionally quantitative environmental health studies (Brown, 2003a).

#### 4. Results

The final selection consisting of 20 articles illustrates that there were few qualitative studies dealing with health risk perceptions of air pollution, especially in the light of the varying local social, economic and political contexts in which populations, hazards and perceptions are situated.

The number of articles was slightly higher during the second decade ( $n = 12$ ) compared to the first decade ( $n = 8$ ). Articles were mainly published in epidemiological and public health journals and addressed communities from all over the world, although mostly Western societies ( $n = 14$ ). First authors originated from a broad range of disciplines: intersection between health (public and environmental) and epidemiology ( $n = 7$ ), geography ( $n = 4$ ), sociology ( $n = 2$ ), urban studies ( $n = 2$ ), environmental education ( $n = 1$ ), environmental management ( $n = 1$ ), environmental engineering ( $n = 1$ ), sustainable development ( $n = 1$ ) and anthropology ( $n = 1$ ).

All articles addressed anthropogenic pollution sources, except a single one that reported on health risk perceptions of air pollution originating from a volcano. Point sources of pollution were of major concern, originating from open cast coal mining ( $n = 1$ ), industry ( $n = 5$ ), waste burning fires ( $n = 2$ ), managed forest fires ( $n = 1$ ), volcano's ( $n = 1$ ), wood fires ( $n = 2$ ) and dump sites ( $n = 1$ ), besides line source pollution originating from transport ( $n = 5$ ). A few articles did not specify the kind of air pollution or focussed more broadly on 'urban air pollution' ( $n = 6$ ). Generally spoken, there was a stronger emphasis on the source of air pollution than on the specific pollutant resulting from this source. If terminology was more precise than 'air pollution', terms like dust, smog, fumes and smoke were used. Articles focussing on specific health topics were rare; most explored risk perceptions for general health ( $n = 14$ ). A few exceptions did concentrate on specific

health outcomes such as asthma ( $n = 1$ ), stress ( $n = 1$ ) or more broadly respiratory problems ( $n = 4$ ).

We will further elaborate on 1) the study designs and methodological approaches used in the selected articles and 2) their contributions to advance the evidence related to health risk perceptions of ambient air pollution in the field of environmental epidemiology.

##### 4.1. Study designs and methodological approaches

Most studies relied on a mere qualitative study design using one single method of data collection ( $n = 15$ ); a minority used a combination of several data collection methods ( $n = 5$ ). Face-to-face interviews were the most frequently used method ( $n = 16$ ); the number of respondents ranging from 14 to 132, with generally shorter questionnaires in case of larger numbers of respondents. There was a lot of variation with respect to the length and depth of the interviews, although precise information hereabout was often missing in the articles. Focus-group discussions were the second most popular method of data collection ( $n = 7$ ); the number of group discussions ranging from one to eight and from 40 to 90 min in duration. Two articles relied on observations and one article on written sources (complaints about smoke exposure from forest fires).

Five articles used a mixed-method study design in which qualitative and quantitative methods were combined, resulting in robust triangulated insights and knowledge. Three articles started with a qualitative analysis and then proceeded with a quantitative analysis. Day (2007) for instance, designed a self-completion questionnaire based on the themes that emerged during the in-depth semi-structured interviews. The questions reflected the categories and wording used by the interviewees themselves as much as possible. The aim of the survey was to build further on the 'lay knowledge' framework and to expand this framework.

Two studies worked the other way round and used qualitative data to generate more in-depth understandings of the quantitatively identified patterns. Quantitative data are needed to determine the existence and extent of environmental health effects, while qualitative data are crucial to understand how people and communities experience and act upon these problems, as quantitative data can only give a partial picture of health effects and their causes (Brown, 2003).

A quantitative research phase preceding the qualitative phase might also ease the recruitment of respondents thereby minimizing time costs and maximizing efficacy and quality. Especially when research urges for different profiles of respondents, it is very difficult and time-consuming to recruit these via other channels. Bush et al. (2001) used a research design in which a postal survey was followed by a semi-structured in-depth interview. Survey respondents were invited to take part in the qualitative interviews and were then selected purposively to reflect a diversified group in terms of age, sex, socio-economic status and health status. As suffering from an illness perceived to be related to air pollution influences opinions on associated health risks, people with such an illness themselves or a family member suffering from such an illness, were purposely selected among the survey respondents.

Coming back to qualitative methods of data collection, it is clear that they can drastically enhance our knowledge and insight in environmental epidemiology. Face-to-face interviews and focus group discussions allow for a broad exploration and a deep understanding of the study theme/topic. They generally use open-ended questions that enable the researcher to make sense of interviewees' responses without pre-determining their answers through fixed response categories and that moreover allow for additional surprising and/or multifaceted responses (Scammell, 2010). Respondents can express themselves, describe their views, attitudes and perceptions by a self-chosen range of words and expressions. The nuances in word choice and expression are of great value in sketching the respondent's perceptions and furthermore gives the respondent the feeling of being well understood, not being obliged to give an answer that fits pre-defined answer categories that do not

necessarily represent what the respondent would like to express. For instance, Day (2006) underlined that respondents expressed uncertainty about the causality between air pollution and respiratory/allergic complaints during the in-depth interviews, while this was not all reflected in the self-completion questionnaire that constrained answers to an obligatory choice between categories.

Another advantage of qualitative data collection is the close contact with the community under study. As researchers are more embedded into the community and its context, they become more easily aware of the place their research occupies within this context and of eventual biases. For example, monitoring campaigns are often considered to be positively valued, to advance knowledge among experts, environmental and public health officials and communities. A study on place-based stressors associated with air pollution originating from an oil refinery in Philadelphia showed however that many respondents were suspicious about monitoring efforts. In particular, respondents witnessed that the refinery, and the proposal to study and thereby reduce pollution, triggered feelings of discrimination, fear of displacement, lack of ownership and residence insecurity. They feared that talking about air pollution, and interventions on its abatement, increased the risk of being priced out of their homes.

Clearly, qualitative methods of data collection, ideally in combination with quantitative methods, have many advantages to enhance knowledge in the field of environmental epidemiology. We will now go in depth about which recent contributions were made by studies relying on qualitative research methods.

#### 4.2. Contributions of qualitative studies in advancing evidence in the field

The current contribution of qualitative studies to the field of environment epidemiology can be summarized in four themes related to the perception of the exposure to air pollution and the perception of its health impact. The first two themes relate to the perception of the exposure: 1) the definition and identification of a hazard; 2) the perception of the degree of exposure to the identified hazard. The last two themes relate to the perception of the effect of the exposure: 3) the perception of the health impact of the hazard; 4) the concern about the health impact of the hazard.

##### 4.2.1. Perception of the exposure to air pollution

People should first recognize an element or condition as a problem or hazard before they will act upon it. We will therefore first list the insights that were generated from the articles in this review, related to the definition and identification of air pollution by laymen. Subsequently, we will elaborate on the perception of the degree of exposure to air pollution.

**4.2.1.1. Definition and identification of air pollution.** Laymen and scientists clearly define air pollution differently. The scientific community focuses on specific pollutants derived from multiple sources; the public rarely refers to specific pollutants but rather emphasises the sources of air pollution. In their study on pupils' knowledge of air pollution in Greece (Dimitriou & Christidou, 2007), observed that the majority referred to specific air pollutants as 'smoke', 'exhaust-gases' or 'harmful substances', without making any distinction between the different substances found in the air.

Knowledge about the sources of air pollution differs as well. Among laymen, air pollution sources are often associated with odour. In the Nairobi slums, for instance, smelly drainage channels and toilets were frequently cited as a source of air pollution (Muindi et al., 2014b). In Beijing (Xu et al., 2017), respondents also mentioned garbage as a source of air pollution thereby considering odour as the clue connecting garbage with air pollution.

Obviously, the classification of elements as contributing to air pollution is context-dependent. People refer to sources of pollution that

are part of their daily lives and the society they live in. Respondents from a London study for instance indicated cars, buses, HGV's and pollen as the most significant causes of air pollution (Day, 2007), while respondents in a poor neighbourhood in Nairobi mostly pointed to road dust, industrial areas and burning trash (Ngo et al., 2017). What people categorize as being air pollution is very much culturally defined. In a community in California, smoke caused by wildland fire was perceived as air pollution (Cisneros et al., 2018). On the contrary, in a study on open burning of municipal solid waste (MSW-burning) in India, respondents expressed the belief that smoke from ceremonial fire is a purifier when good fuel is used (Ramaswami et al., 2016). When asked explicitly if smoke from MSW-burning also purifies, there was consensus that smoke from MSW-burning does not purify and is polluting. The 'pure' character of ceremonial fire smoke relative to MSW-burning smoke was explained through the fuel used for the burning. In a community in Australia, the presentation of wood smoke as natural and the idea that wood heating is a traditional source of warmth counteracts the strong association of pollution with modernity and 'artificial' sources of energy (Reeve et al., 2013).

It is clear that nor definitions about air pollution nor the elements identified as air pollution, are universal and that they not only differ between experts and laymen, but also between different populations in different contexts. In what follows we will elaborate on the perception of the degree of exposure to air pollution.

**4.2.1.2. Perception of the degree of exposure to air pollution.** While the scientific community relies on technical equipment to detect air pollutants and to rate air quality, laymen largely rely on their direct, personal experiences – health and sensory cues – to make inferences about air quality, their exposure and the identification of air pollution sources.

Sensory cues such as visibility and density of pollutants, polluting sources and olfactory evidence make people aware of air pollution in their community. Wakefield et al. (2001), observed that perceived health impacts depend upon visible signs of pollution rather than expert assessment of risks in an urban industrial neighbourhood in Canada. Similarly, Bickerstaff and Walker (2001) showed that many respondents drew visible evidence for the existence of air pollution from the physical concentration of sources. Xu et al. (2017) found that visible and tangible sources of air pollution such as sandstorms were mentioned as polluting sources by respondents whereas intangible pollutants, such as NO<sub>x</sub> and SO<sub>2</sub>, remained unnoticed. Bickerstaff and Walker (2001) observed that respondents related olfactory evidence to particular sources of smells, dominated by car fumes and emissions from local industries. For a number of respondents however the absence or loss of positive smells (e. g. the smell of flowers) rather than the presence of obnoxious industrial or vehicular smells influenced their perception of air quality. Ngo et al. (2017) found that respondents associated air pollution with a 'bad smell,' which may explain why problems of 'sewage' or 'dirty water' were commonly brought up in their research.

The lay perception of air quality is obviously not only influenced by the general quality of the environment and its physical features, but also by culturally constructed landscapes, comparative evidence and the context of place. Related to the physical features, Bickerstaff and Walker (2001) found that the city centre of Birmingham retained its dominance as the most polluted area due to, amongst other elements, the vertical, densely built landscape which was recognised to hinder pollution dispersion. Day (2007) showed that respondents in London perceived air quality in high-altitude places to be better than in other parts of the city.

The general environmental quality also impacts upon the perceived air quality. Bickerstaff and Walker (2001) and Day (2007) observed that low general environmental quality, characterised by low levels of vegetation or greenery, resulted in a negative evaluation of the inner city air quality. Trees in particular were believed to improve the air quality through the production of oxygen and the cleansing of air. The degree of physical degradation (litter, dog fouling, public indifference towards the

environment) was important as well; it informed the wider environmental quality and often influenced air quality perception (Bickerstaff & Walker, 2001). Day (2007) observed that air quality perceptions were partly related to the varying levels of satisfaction with the areas people lived in. In their study of two areas with relatively low levels of (objective) pollution, respondents in the more affluent area mentioned air quality as being one of the positive area attributes making them happy to live there, while in the more disadvantaged area respondents judged the local air quality as 'ok' but did not explicitly mention it as a positively valued good. In this area, respondents rather spoke in terms of the absence of any kind of problem.

Comparative evidence impacts upon the perception of air quality as well. Air quality in places where people stayed for a long period of time often serve as a point of reference to evaluate changes in air quality over time (Xu et al., 2017). Besides time-comparisons, location-based comparisons are at play as well. Bickerstaff and Walker (2001) observed that short-term movements in and out of Birmingham negatively impacted upon air quality perceptions when residents returned from what was consistently recounted as a 'pure' or 'clean' environment. A respondent in the study of Hodgson and Hitchings (2018) commented that she "never really was averse to roads as much in Australia versus here [London] ... because of population and the number of cars that are on the road". The Australian experience made this respondent particularly aware of London's (perceived as bad) air. Comparisons are also made with regard to sources of pollution. Moffatt and Pless-Mullooli (2003) showed that respondents contrasted the impact of opencast mining with that of other industries, such as steel, chemicals, nuclear, even agriculture, against which opencast mining emerged as relatively less polluting.

Day's study (2007) yielded interesting insights into how respondents interpreted air through and as part of a culturally constructed landscape. Central London, an iconic entity, was seen as being air polluted – which seems justified by physical and scientific explanations – but was in a broad sense evaluated as a dirty, bad and unhealthy environment. Poor air was considered as a facet of a bad environment and was often mentioned as part of a general sense of badness and insalubrity that resulted from the presence of litter, crowding and traffic. Places associated with good air quality strongly referred to the countryside and natural environments. Reeve et al. (2013) found that popular perceptions of pollution link pollution to social processes such as urbanization and industrialization. Tainted air is associated with cities; smog and air pollution are typically conceived as urban social problems. Respondents believed air pollution was something that occurred in cities, not in the country town where they lived in. In their study on the attitude of toward urban air pollution in Beijing, Xu et al. (2017) observed that the public's perception is affected by place identity. For instance, the 'identity' of Beijing as the capital gave two respondents the illusion that air pollution was not so severe as the capital is the focus of attention, and attention was believed to bring resources to tackle the problem. Xu et al. (2017) furthermore observed that air quality perception is influenced by psychological effects such as the 'Halo effect,' in which people tend to think the air quality is better in their own neighbourhood than in other neighbourhoods.

Clearly laymen make inferences about air quality, their exposure to it and the identification of its sources based on direct personal experiences rather than on objective measurements. Since, these personal experiences are far from universal; rather strongly context dependent, it is key to understand one's context to better understand health risk perceptions. We will now further elaborate on the perception of the health impact of exposure to air pollution.

#### 4.2.2. Perception of the health impact of air pollution

When air pollution is perceived as a hazard and when people perceive themselves as being exposed to it, it is meaningful to investigate the perception of its health effect. We will start elaborating on the public perception of the health impact of air pollution and continue with the concern given to this perceived health impact of air pollution.

4.2.2.1. *Perception of the health impact of air pollution.* The study of Ngo et al. (2017), on risk perceptions and understandings of air pollution in a poor Nairobi neighbourhood, found that less than half of the respondents explicitly considered health in their definition of air quality. Similarly, only 40,5% of pupils' in Greece considered air pollution as a serious and pressing environmental problem affecting human health (Dimitriou & Christidou, 2007). Both studies illustrate that the link between air pollution and human health is not always obvious among respondents.

This does not imply however that people do not link air pollution with health once air pollution becomes more tangible and people become aware of exposure to air pollution. In general, links between air quality and health are often partial and drawn with uncertainty. To explain this, Bickerstaff and Walker (2001) refer to the inherent causal uncertainty which prevails when one component – in this case the atmosphere – is separated from its holistic context – the environmental system. This causal uncertainty results in a rejection of the physical complaint as if it was 'unreal' or in an alternative causality that attributes the cause of the physical complaint to other elements or characteristics of the environment. Natural (e.g. pollen, temperature, weather) and social (e.g. poverty and poor living conditions) environmental characteristics for instance were more easily identified either as partial or dominant sources of personal health problems. Unlike air pollution, these characteristics, are more tangible and immediate traits of the environment. Respondents in the study of Wakefield et al. (2001) admitted that the risk associated with their own "bad habits", particularly smoking, make it difficult to assess the relative contribution of air pollution to their poor health. They also felt uncomfortable identifying air pollution as the factor responsible for their poor health because they lacked "scientific" knowledge. Bush et al. (2001) showed that respondents rationalised the fear for negative health impacts of air pollution by drawing on a range of other environmental and non-environmental factors that contribute to poor health. Moreover, when respondents talked about the effects of air pollution on their health, they often referred to unspecific effects, a kind of 'generally bad for your health feeling' without insights in the precise mechanisms and with a sense of cumulative effects. Although risks associated with pollution were considered relatively small, they were understood as important representing a tipping point in overall burden (Day, 2006).

Atari et al. (2011) identified several reasons for respondents to link air pollution to health: presumed pollution-related morbidity (e.g. respiratory problems and cancers); mortality within respondents' regional social networks; physical sensing, particularly through smell, of being exposed to pollutants with potential adverse health effects; and the labelling of the area under study as an "Area of Concern"(AOC) highlighting the threat of environmental pollution.

The selected studies illustrate that respondents feel more certain linking health to air pollution when pollution is more sensible (smoke, heavy smell, ...) and its physical impacts more acute (breathing difficulties, eye irritation, feeling burnings in the lungs). Chronic and less tangible exposures are less easily associated with adverse health outcomes.

Many communities exposed to a range of pollutants cited asthma as a specific health outcome of air pollution. The communities residing near opencast coal mines studied by Moffatt and Pless-Mullooli (2003), for instance, cited asthma as the most frequent condition. Although respondents did express some uncertainty in linking asthma to air pollution, they put traffic pollution and opencast forward as common explanations. They did observe increased asthma levels since the opening of the opencast coal mine, but still expressed uncertainty about the reasons for this increase. A number of respondents questioned whether the increase was a 'real' phenomenon or rather resulted from changing thresholds for diagnosis or other extraneous environmental factors. Respondents often used evidence for a zero-health effect by using family members' asthma as a 'barometer' against which they judged health effects. Bickerstaff and Walker (2001) showed that

respondents attributed the rising incidence of childhood asthma to increased diagnosis and over-protective parenting.

In sum, the link between air pollution and human health is not always obvious from a laymen perspective. And when they link the exposure to as air pollution identified elements as harming for their health, this not necessarily means that they are personally concerned about it. We will elaborate on this in the next paragraph.

**4.2.2.2. The concern about the health impact of air pollution.** Awareness and concern are not always synonymous. Individuals can, for instance, be aware of the impacts on other peoples' health but show no concern with the air quality impact on their own health (Bickerstaff & Walker, 2001). The selected studies show that people often employ disassociation strategies in this respect. Bush et al. (2001) for instance explored public risk perceptions of air pollution in a heavily industrialized area in England and observed disassociation strategies whereby respondents acknowledged that air pollution was problematic in their district but not in their own community. It was perceived as a problem faced by others, living closer to the industry ("differentness"). People living in the communities located at a distance from the industrialized spot generally felt that poor health attributable to air pollution was mainly a problem of 'poorer' people living close to the industry. Respondents living in communities that did perceive air pollution as a problem of their own community often felt that this also impacted those living further away from the industry, thereby 'othering' air pollution as a problem ("sameness"). Likewise, Moffatt and Pless-Mulloli (2003) showed that parents of asthmatic children also "othered" health concerns: they were concerned about children whose asthma was worse than that of their own child; while parents of non-asthmatic children expressed concern about children they perceived as more vulnerable than their own, particularly those with asthma. Xu et al. (2017) observed an "optimism bias". Respondents were aware of the adverse health effects associated with air pollution but tended to think that the impact on their own health was minimal. Some interviewees thought they were strong enough to be immune to symptoms induced by air pollution; some recalled past experiences, such as being extensively exposed to second-hand smoke or living in harsher environments. Bickerstaff and Walker (2001) observed that respondents were more willing to admit the negative impacts of air pollution on other peoples' health rather than on their own health. In a study on wood smoke pollution originating from wood heaters in an Australian community, respondents reconciled the dissonance between wood heating and its side effects through three main discursive strategies: denial, diminishment and attribution (Reeve et al., 2013). The denialists considered the haze to be natural mist. Diminishment strategies were often cited, respondents stating that wood smoke had had no health effect in the past, that it was too limited in time or space to have any effect, or that it was not as bad as in the past. Attribution strategies attempted to shift responsibility away from the individual to others, to farmers for instance, low-income households, rental households or recent in-migrants who were considered to be the main cause of the problem, because of their lack of choice or of rural skills.

Xu et al. (2017) furthermore observed that people who were in fact concerned with air pollution tended to be so not only with respect to their own health, but also with that of the future generations. Li and Tilt (2018) found that gender played a key role in the way participants perceived and experienced air pollution. Particularly mothers of young children worried about the effects of air pollution on their children's health. Personal experiences tended to increase concerns with air pollution as well. Xu et al. (2017) found that health concerns were stronger among respondents who suffered from chronic respiratory symptoms or who had experienced direct health effects during heavy pollution episodes. The authors identified several factors that alleviated public concern: feelings of uncontrollability or powerlessness, crowding-out effects, perceived benefits (compensation of perceived

benefits for living in a polluted environment), perceived fairness (everybody perceived as exposed without discrimination), delay of manifestation of health effects and habituation and acceptance.

Effects of crowding-out and perceived benefits were observed in other studies as well, as people face a lot of issues competing for attention in their daily lives. Air pollution induces some concern when considered separately, but this is often 'crowded out' by other more personally relevant and urgent issues – more pressing problems or environmental risks – that require attention (Xu et al., 2017). In a community living close to a rail yard in California, for instance, respondents expressed a concern about the poor air quality but perceived other challenges as more urgent (Spencer-Hwang et al., 2014). While they considered air pollution as negative, they clearly placed it further down their priority list. A recent study of Becerra et al. (2020) assessed the characterization of the 'risk culture' of air pollution in Cote d'Ivoire. Faced with risks perceived as major, such as accidents or assaults, air pollution was seen as a secondary problem or even simply as an 'ordinary inconvenience' to be tolerated or resisted to rather than prevented. In some cases, environmental risks are even recast as opportunities. Becerra et al. (2020) found that dump site workers made reference to the dump as 'life-saving', a place of opportunities, providing work, income and even luck instead of being dangerous. These insights might lead us to expect that the impact of air pollution on health is crowded out more often in precarious communities. Bickerstaff and Walker (2001) found an inverse relationship however between socio-economic status and concern for local air quality. People living in the high-status neighbourhoods voiced the least concern, while those in the 'low class' area expressed much stronger worries.

Another conclusion is that risks associated with air pollution are often overshadowed by other environmental risks, including the presence of a sewage treatment plant, a planned expressway through a nearby natural area, dangerous driving, litter, abandoned and/or deteriorating buildings, uncontrolled animals and crime (Wakefield et al., 2001). Similarly, Hodgson and Hitchings (2018) showed, in their study on how urban air pollution insinuates itself into the consciousness of recreational runners in London, that perceptions of the benefits of running crowded-out any concerns with exposure to pollution. The perception of running as an activity with positive health effects offering the opportunity to be outside in the 'fresh air' was so strong that it sealed the respondents inside a protective mental bubble repelling the idea of negative pollution effects.

As briefly touched upon already, the perceived benefits linked to the sources of air pollution might also impact the concern about air pollution. Muindi et al. (2014b) observed that dumpsite workers in Nairobi relied on the dumpsite as a source of livelihood. One respondent stated that it had created employment for 30% of the population and caused 5% deaths. Likewise, Moffatt and Pless-Mulloli (2003) noted that jobs generated by the opencast coal mines were considered of great importance especially in the light of the high unemployment levels and the lack of nearby alternative employment. Employment was viewed in terms of local gains as a kind of 'pay off' in return for the inconvenience and disruption caused by the site. Reeve et al. (2013) studied the rhetoric of resistance to wood heater regulation in Australia, in a town where wood smoke levels regularly exceed national health advisory limits. Respondents emphasized the positive associations of wood heating such as 'welcoming', 'comforting', 'cosy' and 'attractive'. Wood heating was associated with security of warmth, enduring warmth, physical exercise and connection to the land, and vivid childhood memories of social activities with family. Another, the most frequently cited positive aspect of wood heating was considered to be its cost. In sum, positive associations and economic benefits related to the source of pollution clearly impact upon the concern given to this pollution.

To conclude with, the research findings illustrate that qualitative research can contribute to novel, context-dependent, nuanced and multi-layered insights in the field of environmental epidemiology as is schematically presented in Fig. 1.



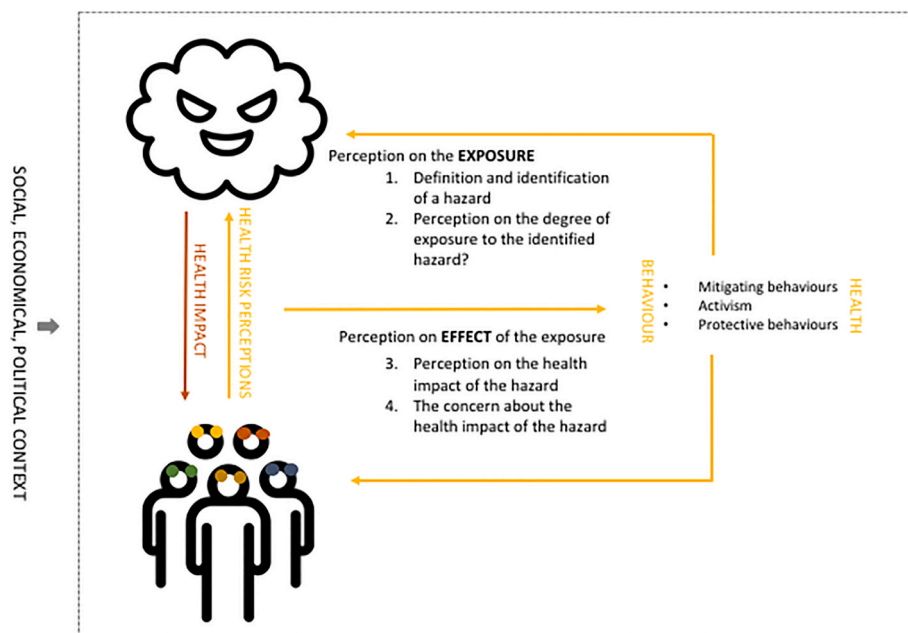


Fig. 1. Schematic overview of the contributions to the field of environment epidemiology.

The research findings illustrate that laymen must first recognize an element or condition as a hazard, that they must perceive themselves as exposed to this identified hazard, that this hazard must be perceived as negatively impacting their health and as something they are concerned about before they might act upon it. So, different health risk perceptions might contribute to the differential display of reactions or behaviours in terms of tenacity such as mitigating behaviours (changes in mobility) that might mitigate the hazard or activism and protective behaviours (avoiding places with high levels of air pollution) that might mitigate the exposure and effect of the hazard. It is apparent that both the perception of an exposure and the perception of the effect of an exposure are influenced by the social, economic and political context in which they are formed. Indeed, we learned that both definitions about air pollution and the elements identified as air pollution are far from universal and that they might differ between experts and laymen, but also between different populations in different contexts. Also inferences about air quality, the exposure to air pollution and the identification of its sources might differ between experts and laymen. Laymen's inferences are often grounded in personal experiences that are far from universal and strongly context dependent. Also the link between air pollution and human health is not always an obvious one from a laymen's perspective. And if a link is drawn, this not automatically results in a concern about it.

## 5. Discussion

In the light of the well-established proof for the negative health impact of air pollution and the mediation of this impact through risk perceptions, it is crucial to understand lay perceptions about air pollution. Since qualitative research methods are well suited for this aim, our review focussed on qualitative research on public health risk perceptions of ambient air pollution since the 2000s.

The aim of this review was twofold. We firstly investigated which different study designs and methodological approaches have been used to study this topic. Secondly, we synthesized the contributions of the selected articles in terms of advancing the evidence in the field of environmental epidemiology.

Concerning the first focus of this review, the use of qualitative research seems not to have evolved considerably since previous reviews (Bickerstaff, 2004; Saksena, 2011; Scammell, 2010) and continues to be

scarce in the field of environmental epidemiology. Our review showed that qualitative research designs are exceptional in this field of study and that mixed-method designs, although fruitful in complementing or triangulating findings, are even more scarce. The most popular research instruments were face-to-face interviews and focus group discussions allowing for broad and deep explorations, descriptions and interpretations.

Secondly, this overview of qualitative articles on the perception of exposure to air pollution showed that air pollution in the public's mind is not at all the same as air pollution defined by the scientific community. Not only the ideas about air pollution sources differ between experts and the public, but also the rating process of air quality. The scientific community obviously relies on technical equipment to detect air pollutants and to rate air quality, while the public largely relies on direct, personal experiences, mainly health and sensory cues such as the visibility and density of pollutants, polluting sources and olfactory evidence. The lay perception of air quality is attenuated or augmented by physical features of the environment, comparative evidence, the general environmental quality, culturally constructed landscapes and the context of place. The categorization of an element as being air pollution is thus context-dependent and therefore nor objective, nor universal.

Related to the perception of the health effect of the exposure to air pollution, our review illustrated that the link between air pollution and human health is not always obvious and that if the link is drawn, it is done with uncertainty, often partially and in terms of unspecific effects. Nevertheless, the more sensible the nature of the pollution and the more acute the physical impact of it, the more certainty is expressed in linking air pollution and health. It is also clear that awareness and concern about the health impact of air pollution are not synonymous. The public often employs dissociative and discursive strategies such as denial, diminishment and attribution. In addition, factors such as uncontrollability or powerlessness, crowding-out effects, perceived benefits, perceived fairness and delay of health effects and habituation might alleviate public concern. On the other hand, personal experiences tend to increase concern about air pollution.

While in general the exposure to and the effect of a hazard is assessed by experts relying on technical equipment, uniform procedures and objective data, laymen's assessments are on the contrary subjective, context-specific and personal. Therefore, in order to stimulate people to mitigate air pollution or in order to stimulate them to take appropriate

measures to protect themselves against possible negative health outcomes, it is key to generate insights in these risk perceptions. These health risk perceptions should be taken seriously since, the dismissal of public concerns when they are not supported by statistical evidence appears to generate distrust rather than offer reassurance (Randler et al., 2020).

In the case of new implementations such as urban and industrial projects, before possible perceived hazards are installed, the participation of local communities and the understanding of risk is important in order to avoid or limit negative psychosocial health and wellbeing effects and to maintain community well-being (Baldwin et al., 2020).

Stewart et al. (2010) conclude in this respect that good communication and public involvement from an early stage is essential for generating trust and when this happens, even though the outcome of an investigation is not what is expected, or hoped for, it is accepted by the public.

As stated before, we believe that qualitative research methods and mixed-method-approaches are most effective in this respect and might offer to a community the feeling of being heard and involved.

There is however no ideal one fits all study design. The study design depends of many factors, such as the available resources in terms of expertise, financial means and time. Since environmental epidemiology is mainly a quantitative discipline, expertise to conduct qualitative research might be lacking. It is therefore important to collaborate with other disciplines or with multidisciplinary teams with researchers experienced in doing qualitative research in order to overcome this issue.

Whether a qualitative research phase better proceeds a quantitative research phase or the other way around when a mixed-method is employed, is study-case specific. For the development of a pertinent self-completion questionnaire it is advisable to start with qualitative research in order to create a questionnaire that reflects the categories and wordings used by the studied population. On the other hand, when one aims to generate more in-depth understandings of quantitatively identified patterns, a qualitative research phase succeeding a quantitative one is more appropriate. Other reasons to start with a qualitative phase are getting familiar with the population, gaining trust among the population, giving a human face to the researchers and research institutions, creating openness and an empathic, human and participative atmosphere.

In terms of qualitative research instruments, we believe that observations and the analysis of written sources alone, might not generate sufficiently rich data to understand health risk perceptions properly. On the other hand, in combination with other research instruments – especially in a sequential design – they might be complementing. We believe that face-to-face interviews and focus group discussions – research instruments that were among the most popular in the reviewed articles – might be the best-suited research instruments as they allow for broad and deep explorations, descriptions and interpretations of contextual lay risk perceptions. Of course, there might be other appropriate research instruments that were not used in the reviewed articles. The study of Börner et al. (2015) might be inspiring in this respect. They explored Mexican adolescents' perceptions of environmental risk by using an environmental photography technique. The technique was used in combination with in-depth interviews and produced community narratives that gave voice to the participants, described the local context in a comprehensive way, captured and transmitted complex information which often cannot be expressed in words and overcame language or cultural barriers.

Whether one uses only qualitative research methods or makes use of a mixed-methodology, it seems advisable to make use of a sequential research design involving sequential explanatory aspects in order to generate pertinent insights. The research design proposed by Baldwin et al. (2020) might be inspiring in this respect. They introduced a mixed qualitative and quantitative approach to construct models and scales measuring well-being and its influences. The methodology they propose

consists of four steps: 1) a public information campaign; 2) community workshops; 3) a questionnaire survey, and 4) community feedback and refinement workshops. Their research design nicely illustrates how it allows for triangulation of the obtained data whereby the qualitative and quantitative data can be triangulated to cross-check how large-scale survey responses compare to the more in-depth workshop responses. Quantitative data allow for the identification of trends, qualitative data allow for the identification of discrepancies, exceptions, anomalies and nuances in these responses.

We should acknowledge that although qualitative research methods have many benefits, there are also some disadvantages or difficulties involved. Qualitative research – especially in a mixed-method setting – might be more time and budget consuming (initiating contacts and networks, build trust, find respondents, make transcripts, ...). So, even though using qualitative research methods in a research design will provide more holistic explanations for environmental health research, their implementation might be challenging when financial means or time are limited.

This research has some limitations. The articles discovered by the search engines do not represent the entire realm of qualitative environmental health-risk-perception research. As mentioned before, this literature review excluded books, book chapters, and 'grey literature' (e.g., technical reports, working papers) that may bring a substantial contribution to the field of environmental health. In addition, as search engines are limited in their ability to identify and categorize qualitative studies because of the indexing practices of electronic databases, we would like to express reluctance about the completeness of our review. In particular, the titles and abstracts used to index qualitative studies often do not explicitly include research methods.

Despite multiple arguments in favour of implementing qualitative research designs to contribute to a better exploration, description and interpretation of health risk perceptions and the thereof resulting behaviours or attitudes, they are definitely under-used. This may be due to the fact that the option to include qualitative research methods is not top-of-mind during the decision-making-process of the study-design, to an underestimation of the contributing power of qualitative research methods or due to a lack of familiarity with them. Hereby we acknowledge that the field of environmental epidemiology is a traditionally quantitative discipline and that most epidemiologists are not professionally trained to conduct qualitative research. We therefore point to the importance of collaborations with qualitative researchers in multidisciplinary teams to conduct mixed methods research.

With this review we hope to have awakened or increased awareness among environmental epidemiologists for the option to also include qualitative research methodologies in their studies/interventions possibly through mixed methods multidisciplinary research collaborations and to convince them from the fact that data generated through qualitative research provide a complement to quantitative epidemiology research. Indeed, qualitative research can create added-value through the triangulation of findings, the development of pertinent questions, the generation of in-depth understandings of quantitatively identified patterns and additional surprising and/or multifaceted responses, the generation of nuanced findings, building trusted relationships between researcher and respondent, getting aware of important context-dependent dynamics or interactions that may generate biases and through grasping the local, contextual, situational and cultural elements that interact with health risk perceptions.

#### Author statements

CHARLOTTE NOËL: Conceptualization, Methodology, Formal analysis, Investigation, Writing – Original Draft.

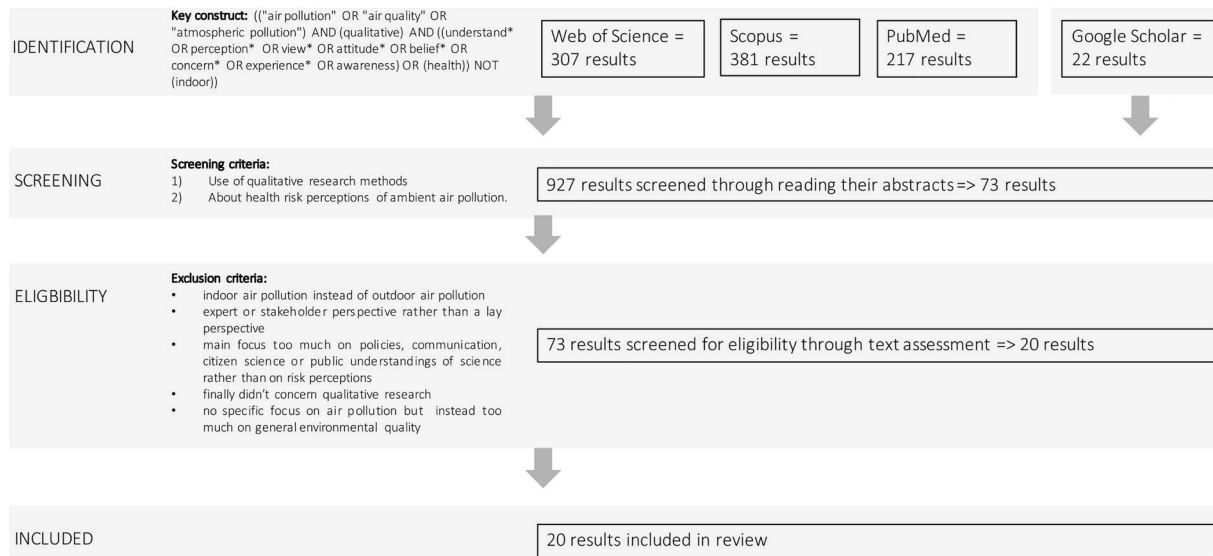
CHRISTOPHE VANROELEN: Writing – Review & Editing, Supervision, Funding acquisition.

SYLVIE GADEYNE: Writing – Review & Editing, Supervision, Funding acquisition.

## Funding

We performed this research within the framework of the Green&Quiet Brussels project, funded by Innoviris, the regional institute for research and innovation of the Brussels Capital Region. Innoviris was not involved in the study design, the collection, analysis or interpretation of data, or the decision to submit this paper for publication.

## Annexes.



Annex 1. Decision tree review process.

## References

- Atari, D. O., Luginaah, I., & Baxter, J. (2011). "This is the mess that we are living in": Residents everyday life experiences of living in a stigmatized community. *GeoJournal*, 76(5), 483–500. <https://doi.org/10.1007/s10708-010-9365-7>
- Baker, D., Kjellstrom, T., Calderon, R., & Pastides, H. (1999). Environmental epidemiology: A textbook on study methods and public health applications. Organization, W. H., & Health, O. and E. H. T. In D. Baker, T. Kjellstrom, R. Calderon, & H. Pastides (Eds.), (*Preliminar*). Geneva: World Health Organization.
- W. H. Organization., & O. and E. H. T. Health <https://apps.who.int/iris/handle/10665/66026>. Retrieved from
- Baldwin, C., Cave, B., & Rawstorne, P. (2020). Measuring the impact of public understandings of risk from urban and industrial development on community psychosocial well-being: A mixed methods strategy. *International Journal of Community Well-Being*, 3(1), 57–82. <https://doi.org/10.1007/s42413-019-00041-x>
- Becerra, S., Belland, M., Bonnassieux, A., & Lioussse, C. (2020). 'Living with' air pollution in abidjan (Cote d'Ivoire): A study of risk culture and silent suffering in three occupational areas. *Health, Risk & Society*, 22(1), 86–106. <https://doi.org/10.1080/13698575.2020.1721443>
- Bickerstaff, K. (2004). Risk perception research: Socio-cultural perspectives on the public experience of air pollution. *Environment International*, 30(6), 827–840. <https://doi.org/10.1016/j.envint.2003.12.001>
- Bickerstaff, K., & Walker, G. (2001). Public understandings of air pollution: The "localisation" of environmental risk. *Global Environmental Change*, 11(2), 133–145. [https://doi.org/10.1016/S0959-3780\(00\)00063-7](https://doi.org/10.1016/S0959-3780(00)00063-7)
- Bickerstaff, K., & Walker, G. (2003). The place (s) of matter: Matter out of place—public understandings of air pollution. *Progress in Human Geography*, 27(1), 45–67. <https://doi.org/10.1191/0309132503ph4120a>
- Börner, S., Albino, J. C. T., Caraveo, L. M. N., & Tejada, A. C. C. (2015). Exploring Mexican adolescents' perceptions of environmental health risks: A photographic approach to risk analysis. *Ciencia e Saude Coletiva*, 20(5), 1617–1628. <https://doi.org/10.1590/1413-81232015205.11382014>
- Brooks, S., Sutherland, C., Scott, D., & Guy, H. (2010). Integrating qualitative methodologies into risk assessment: Insights from South Durban. *South African Journal of Science*, 106(9/10), 1–10. <https://doi.org/10.4102/sajs.v106i9/10.324>
- Brown, P. (2003). Qualitative methods in environmental health research. *Environmental Health Perspectives*, 111(14), 1789–1798. <https://doi.org/10.1289/ehp.6196>
- Bush, J., Moffatt, S., & Dunn, C. (2001). "Even the birds round here cough": Stigma, air pollution and health in Teesside. *Health & Place*, 7(1), 47–56. [https://doi.org/10.1016/S1353-8292\(00\)00037-X](https://doi.org/10.1016/S1353-8292(00)00037-X)
- Casas, L., Cox, B., Bauwelinck, M., Nemery, B., Deboosere, P., & Nawrot, T. S. (2017). Does air pollution trigger suicide? A case-crossover analysis of suicide deaths over the life span. *European Journal of Epidemiology*, 32(11), 973–981. <https://doi.org/10.1007/s10654-017-0273-8>
- Chen, H., Kwong, J. C., Copes, R., Hystad, P., van Donkelaar, A., Tu, K., & Burnett, R. T. (2017). Exposure to ambient air pollution and the incidence of dementia: A population-based cohort study. *Environment International*, 108(May), 271–277. <https://doi.org/10.1016/j.envint.2017.08.020>
- Cisneros, R., Alcala, E., Schweizer, D., & Burke, N. (2018). Smoke complaints caused by wildland fire in the southern Sierra Nevada region, California. *International Journal of Wildland Fire*, 27(10), 677–683. <https://doi.org/10.1071/WF18060>
- Clifford, A., Lang, L., Chen, R., Anstey, K. J., & Seaton, A. (2016). Exposure to air pollution and cognitive functioning across the life course – a systematic literature review. *Environmental Research*, 147, 383–398.
- Day, R. J. (2006). Traffic-related air pollution and perceived health risk: Lay assessment of an everyday hazard. *Health, Risk & Society*, 8(3), 305–322. <https://doi.org/10.1080/13698570600871869>
- Day, R. (2007). Place and the experience of air quality. *Health & Place*, 13(1), 249–260. <https://doi.org/10.1016/j.healthplace.2006.01.002>
- Dimitriou, A., & Christidou, V. (2007). Pupils' understanding of air pollution. *Journal of Biological Education*, 42(1), 24–29. <https://doi.org/10.1080/00219266.2007.9656103>
- Health Effects Institute. (2018). State of Global Air 2018. A special report on global exposure to air pollution and its disease burden. Boston, MA. Retrieved from [https://www.stateofglobalair.org/resources?resource\\_category=All&page=1](https://www.stateofglobalair.org/resources?resource_category=All&page=1).
- Hodgson, A., & Hitchings, R. (2018). Urban air pollution perception through the experience of social practices: Talking about breathing with recreational runners in London. *Health & Place*, 53(March), 26–33. <https://doi.org/10.1016/j.healthplace.2018.07.009>
- Lima, M. L. (2004). On the influence of risk perception on mental health: Living near an incinerator. *Journal of Environmental Psychology*, 24(1), 71–84. [https://doi.org/10.1016/S0272-4944\(03\)00026-4](https://doi.org/10.1016/S0272-4944(03)00026-4)
- Li, X., & Tilt, B. (2018). Perceptions of quality of life and pollution among China's urban middle class: The case of smog in tangshan. *China Quarterly*, 234, 340–356. <https://doi.org/10.1017/S0305741017001382>

- Merrill, R. M. (2008). *Environmental epidemiology: Principles and methods*. Sudbury, Mass: Jones and Bartlett Publishers.
- Moffatt, S., & Pless-Mullooli, T. (2003). "It wasn't the plague we expected." Parents' perceptions of the health and environmental impact of opencast coal mining. *Social Science & Medicine*, 57(3), 437–451. [https://doi.org/10.1016/S0277-9536\(02\)00369-6](https://doi.org/10.1016/S0277-9536(02)00369-6)
- Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2010). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *International Journal of Surgery*, 8(5), 336–341. <https://doi.org/10.1016/j.ijsu.2010.02.007>
- Muindi, K., Egondi, T., Kimani-Murage, E., Rocklov, J., & Ng, N. (2014a). "We are used to this": A qualitative assessment of the perceptions of and attitudes towards air pollution amongst slum residents in Nairobi. *BMC Public Health*, 14(1), 1–9. <https://doi.org/10.1186/1471-2458-14-226>
- Muindi, K., Egondi, T., Kimani-Murage, E., Rocklov, J., & Ng, N. (2014b). "We are used to this": A qualitative assessment of the perceptions of and attitudes towards air pollution amongst slum residents in Nairobi. *BMC Public Health*, 14(1), 1–9. <https://doi.org/10.1186/1471-2458-14-226>
- Ngo, N. S., Kokoyo, S., & Klopp, J. (2017). Why participation matters for air quality studies: Risk perceptions, understandings of air pollution and mobilization in a poor neighborhood in Nairobi, Kenya. *Public Health*, 142(August), 177–185. <https://doi.org/10.1016/j.puhe.2015.07.014>
- Pidgeon, N. F., Hood, C., Jones, D., Turner, B. A., & G, R. (1992). Risk perception. In Royal Society Study Group (Ed.), *Risk analysis, perception and management* (pp. 89–134). London: Royal Society.
- Rajagopalan, S., Al-Kindi, S. G., & Brook, R. D. (2018). Air pollution and cardiovascular disease. *Journal of the American College of Cardiology*, 72(12), 2054–2070.
- Ramaswami, A., Baidwan, N. K., & Nagpure, A. S. (2016). Exploring social and infrastructural factors affecting open burning of municipal solid waste (MSW) in Indian cities: A comparative case study of three neighborhoods of Delhi. *Waste Management & Research*, 34(11), 1164–1172. <https://doi.org/10.1177/0734242X16659924>
- Randler, C., Tryjanowski, P., Jokimäki, J., Kaisanlahti-Jokimäki, M. L., & Staller, N. (2020). SARS-CoV2 (COVID-19) pandemic lockdown influences nature-based recreational activity: The case of birders. *International Journal of Environmental Research and Public Health*, 17(19), 1–16. <https://doi.org/10.3390/ijerph17197310>
- Reeve, I., Scott, J., Hine, D. W., & Bhullar, N. (2013). "This is not a burning issue for me": How citizens justify their use of wood heaters in a city with a severe air pollution problem. *Energy Policy*, 57, 204–211. <https://doi.org/10.1016/j.enpol.2013.01.042>
- Saenen, N. D., Martens, D. S., Neven, K. Y., Alfano, R., Bové, H., Janssen, B. G., ... Nawrot, T. S. (2019). Air pollution-induced placental alterations: An interplay of oxidative stress, epigenetics, and the aging phenotype? *Clinical Epigenetics*, 11(1), 1–14. <https://doi.org/10.1186/s13148-019-0688-z>
- Saksena, S. (2011). Public perceptions of urban air pollution risks. *Risk, Hazards & Crisis in Public Policy*, 2(1), 19–37. <https://doi.org/10.2202/1944-4079.1075>
- Sass, V., Kravitz-Wirtz, N., Karceski, S. M., Hajat, A., Crowder, K., & Takeuchi, D. (2017). The effects of air pollution on individual psychological distress. *Health & Place*, 48, 72–79. <https://doi.org/10.1016/j.healthplace.2017.09.006>
- Scammell, M. K. (2010). Qualitative environmental health research: An analysis of the literature, 1991–2008. *Environmental Health Perspectives*, 118(8), 1146–1154. <https://doi.org/10.1289/ehp.0901762>
- Slovic, P. (2000). *The perception of risk*. London: Earthscan Publications.
- Spencer-Hwang, R., Montgomery, S., Dougherty, M., Valladares, J., Rangel, S., Gleason, P., & Soret, S. (2014). Experiences of a rail yard community: Life is hard. *Journal of Environmental Health*, 77(2), 8–17.
- Stewart, A. G., Luria, P., Reid, J., Lyons, M., & Jarvis, R. (2010). Real or illusory? Case studies on the public perception of environmental health risks in the north west of England. *International Journal of Environmental Research and Public Health*, 7(3), 1153–1173. <https://doi.org/10.3390/ijerph7031153>
- Wakefield, S. E. L., Elliott, S. J., Cole, D. C., & Eyles, J. D. (2001). Environmental risk and (re)action: Air quality, health, and civic involvement in an urban industrial neighbourhood. *Health & Place*, 7(3), 163–177. [https://doi.org/10.1016/S1353-8292\(01\)00006-5](https://doi.org/10.1016/S1353-8292(01)00006-5)
- Wynne, B. (1992). *Misunderstood misunderstanding: Social identities and public uptake of science*. Public Understanding of Science. <https://doi.org/10.1088/0963-6625/1/3/004>
- Xu, J., Chi, C. S. F., & Zhu, K. (2017). Concern or apathy: The attitude of the public toward urban air pollution. *Journal of Risk Research*, 20(4), 482–498. <https://doi.org/10.1080/13669877.2015.1071869>