COMMUNICATING THE RISKS OF URBAN AIR POLLUTION TO THE PUBLIC. A STUDY OF URBAN AIR POLLUTION INFORMATION SERVICES

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ABSTRACT

Communicating to the public about urban air pollution is a complex task. It requires careful consideration of the goals and objectives of the communication, the target audience, the type of information and the messages to be conveyed, and the vehicles through which the message will be delivered. This complexity increases when the goal of communication is not only making information about air pollution available to the public, but also to promote socially beneficial changes in the behavior of various social groups. In order to understand in greater depth the challenges of communicating different air pollution issues, we evaluated the public air pollution information services provided by public information services in four Spanish cities, based on interviews with experts and a documentary analysis. We identified the main features in terms of five dimensions (goals of communication, type of information, communication mechanisms, intended audience and intended effects), then we explored the limitations of these information systems, and analyze the beliefs and assumptions of the experts concerning communicating with the public. We recommend that air quality management planners assess their opportunities to foster both a broader public engagement and behavioral modifications in a way that complements and extends current structural and informational interventions.

RESUMEN

La comunicación al público sobre contaminación atmosférica urbana es una tarea compleja. Se requiere de una cuidadosa consideración de las metas y objetivos de la comunicación, del público al cual se quiere dirigir, del tipo de información y de los mensajes que se desean transmitir. así como de los vehículos a través de los que se transmitirá el mensaje. Esta complejidad aumenta cuando el objetivo de la comunicación no sólo es poner a disposición del público información sobre la calidad del aire, sino también promover cambios en el comportamiento de los diferentes grupos sociales involucrados. Para entender con mayor profundidad los retos de la comunicación social en el ámbito de la contaminación del aire, analizamos los servicios de información pública disponibles sobre el tema en cuatro ciudades españolas a partir de entrevistas

con expertos y un análisis documental.. Identificamos las principales características de estos sistemas de información de acuerdo con cinco dimensiones (objetivos de la comunicación, tipo de información, mecanismos de comunicación, audiencia y efectos esperados), además exploramos las limitaciones de dichos sistemas y analizamos las creencias y suposiciones de los expertos en relación con la comunicación con el público. Recomendamos que los responsables de las agencias de calidad del aire consideren sus oportunidades para fomentar una mayor implicación pública así como motivar cambios conductuales que complementen y amplíen las intervenciones estructurales y de información actuales.

INTRODUCTION

Although the air quality in European cities has improved significantly in recent decades, millions of European citizens are still exposed to elevated levels of urban air pollutants linked to adverse health outcomes (Guerreiro *et al*. 2013, WHO 2013). Urban air pollution is a complex of hazardous gaseous and particulate matter (PM). Anthropic sources include car combustion engines, solid-fuel combustion for energy production in households and industry, industrial activities such as building or manufacture of cement, and erosion of road surfaces by traffic and the abrasion of brakes and tires (WHO 2013). Due to the diversity in the sources of pollution and its potential health effects, the management of urban air quality poses significant challenges for local governments across Europe, from the implementation of effective environmental monitoring and reporting programs to the design and implementation of policies and interventions intended to reduce health risks from air pollution (Krzyzanowski *et al*. 2005, WHO 2013).

Interventions aimed at reducing the health effects of urban air pollution range from regulatory measures (e.g. stricter air quality standards) to structural changes (such as land-use planning or changing modes of transport) as well as measures aimed at fostering behavioral changes in individuals (e.g. adoption of cleaner modes of transportation or reducing exposure to pollution) (WHO 2013). Regulatory and structural measures are frequently the main objective of air quality planning, but interventions with the goal of influencing the attitudes and behaviors of individuals towards air pollution also play an important role, especially when the aim is to reduce the exposure of individuals and vulnerable groups to air pollution. Questions such as how to communicate the risks of air pollution more clearly, how to engage the public in air pollution issues more closely, and how to produce sustainable changes in individuals' habits and behaviors more effectively become critical in this context (Skov *et al*. 1991, Bush *et al*. 2001, APHEIS 2004, Wartenberg 2009).

In European Union (EU) cities, interventions intended to foster attitudinal and behavioral changes towards air pollution among the public are usually encompassed by the "public information" activities required under EU law (González Ortiz 2013). The information to be made available to the public regarding ambient air quality is set out in EU Directive 2008/50/EC. This includes topics ranging from forecasts to information on observed exceedances of alert thresholds, the types of population concerned, possible health effects, recommended behavior and preventive action to reduce pollution and/or exposure to it. At present the information required under EU legislation is provided to the public by most EU cities, generally through special websites and reports (González Ortiz 2013).

However, communicating the risks of urban air pollution to the public is still a significant challenge for urban air quality management (Beaumont *et al*. 1999, APHEIS 2004, Krzyzanowski *et al*. 2005, Gordon Sanderson *et al*. 2006, Wartenberg 2009, Johnson 2012, Vallejos and Oñate 2013, Taylor and McMillan 2013). Firstly because there are external (to the agency or program) barriers to effective communication, which range from the character of air pollution data (Shooter and Brimblecombe 2009) to the low level of public awareness and use of air quality information services (Saksena 2011), current public perceptions of information on air pollution as either too technical and difficult to interpret or as meaningless and of no value (Bickerstaff and Walker 1999, Bush *et al*. 2001), and the often ignored complexity of influencing individual behaviors, all of which results in a low level of public compliance with advisories aimed at affecting behavior during air pollution episodes (Evans *et al*. 1988, Skov *et al*. 1991, Stieb *et al*. 1996, Johnson 2003, Wen *et al*. 2009, Semenza *et al*. 2008, Sexton 2011). Secondly, because, as in other fields of risk communication, there are a number of internal barriers (to the agency)

to communication in public agencies. Among others, inadequate resources, internal politics or a mismatch of authority or responsibility with the appropriate skills (Johnson and Chess 2006), a lack of knowledge, sensitivity, training and skills needed for effective risk communication (Chess *et al.* 1995, Fischhoff 1995), and poor assumptions about audiences (Covello 1992).

Although a number of studies have investigated air pollution information (APHEIS 2004, Shooter and Brimblecombe 2009, Wartenberg 2009, Plaia and Ruggieri 2011, Chen *et al.* 2013), very little published research has examined public air quality communication services across European cities. Recent evaluations of these services in the EU (Van den Elshout 2008, González Ortiz 2013) have concluded that the information required by the legislation is generally provided to the public. Most cities provide frequently updated information on air pollutant concentrations through websites, reports and mobile apps (González Ortiz 2013). According to these studies the agencies responsible perceive the need to further public awareness of air quality and to obtain more feedback from the public on air quality issues. There is also the perception that wider diffusion of air quality information is needed through the mass media and social media, as well as the adoption of a common air quality index.

In Spain, the last two decades have witnessed the development of air quality information systems based mainly on the provision of advisories and alerts and updated information on air quality levels to the public. In compliance with national laws implemented in the wake of EU directives, regional and local authorities are now responsible for developing air quality plans and implementing measures to improve the quality of the atmosphere. In the main Spanish cities local and regional authorities coordinate in providing information about air quality levels to citizens through various channels (mainly the Internet) and also in running the air quality advisory system, through which the authorities alert the media, send text messages to citizens who have requested them, broadcast updates on electronic street panels, etc. In recent years the air quality information system has been criticized as being too passive and as ineffective in engaging the public (Ecologistas en Acción 2013). In this sense, the Plan Nacional de Calidad del Aire y Protección de la Atmósfera 2013-2016 or Plan Aire (National Air Quality Plan) from the Ministerio de Agricultura, Alimentación y Medio Ambiente (Spanish Department of the Environment) has recently outlined the need for further efforts to promote a higher level of public awareness concerning air pollution, and to invest more resources in pro-active environmental and health education on the topic. But very few studies have examined the systems in place in Spanish cities for communicating with the public on air pollution.

The study

This paper reports the results of a study based on interviews with members of public agencies, experts and representatives of nongovernmental organizations and on a documentary analysis of local air pollution plans and related reports of the air quality information systems put in place by local and regional government agencies in four Spanish cities: Madrid, Barcelona, Zaragoza and La Coruña.

In Madrid the air quality information system is run by the local environmental agency as part of the general air quality system, and as established by the Madrid Air Quality Plan 2011-2015. Among other measures the local agency provides real-time information on air quality levels in the city, and alerts the media, responsible agencies and the general public during air pollution episodes.

In Barcelona the air quality information system is managed by the Catalan Departament de Territori i Sostenibilitat (Land and Sustainability Department), which provides information on air quality levels through the Internet, as well as alerting the media and posting messages on electronic freeway panels during air pollution episodes. This regional department has recently developed a new Air Quality Plan. The local government also developed an Air Quality Plan in 2013 and is currently setting up a website specifically devoted to air quality.

In Zaragoza, the local environmental agency has provided air quality information to the public since 1993 via electronic boards, the media and the Internet. Air quality in Zaragoza has improved significantly in the last five years, due mainly to reductions in traffic volume.

In La Coruña, the local and regional agencies coordinate to provide information about air pollution to the public. The local environmental agency has been very active in disseminating information on air pollution via a special website and various other channels. Local air quality information is routinely made available to the public.

This study aims to analyze some key areas that characterize these systems: i) the goals of communication, ii) the types of information provided to the public, iii) the information mechanisms, iv) the intended audiences and v) the effects of information

actions. Our analysis relies on the general communication framework (Berlo 1960) as well as on McGuire's communications-persuasion framework (McGuire 1968). The central idea of these models is that features of the communication 'input factors' – the source of a message, the message itself, the channel through which it is distributed, and characteristics of the receiver - together generate possible communication outcomes, termed 'output factors' or effects (Bull *et al.* 2001, Brunsting *et al.* 2011, Berger 2014).

In addition, we explore the beliefs and assumptions held by experts regarding communications with the public about air pollution. The main features and basic assumptions and ideas underlying air pollution information systems remain to be documented. The goal of the study is to explore the strengths and limitations of these systems and to frame recommendations for developing broader communication programs, in terms of both scope and rationale.

METHOD

Semi-structured interviews

Semi-structured interviews were conducted with 20 experts in the field of air pollution. The purpose was to understand what key stakeholders feel are the critical issues facing communications on the topic in Spain. In choosing the participants we used a combination of purposive and snowball sampling (Patton 2002). The selection of respondents was initially based on our own knowledge regarding which people would best be able to inform our study. We sought to conduct interviews with persons in four areas related to air pollution communications: workers in air quality agencies, technical experts working in air quality agencies, researchers, and members of non-governmental associations. Participants included 10 staff members from local air quality agencies in four cities (Madrid, Barcelona, Zaragoza and La Coruña) and three members of central state and regional agencies.

An open-ended interview protocol was developed to ensure that all interviewees were asked the same questions. The protocol concentrated on five key themes: i) goals and challenges of communication, ii) types of information provided, iii) vehicles for conveying information, iv) intended audiences and v) effects of information. Interviews were completed between July and December 2013. Some were conducted face-to-face and others via telephone. Interviews ranged from 20 to 80 minutes in length.

Documentary analysis

In addition to the interviews and in order to understand the main features of the air quality information systems in place in the cities under study, we gathered and analyzed official and non-official documents regarding air quality management and public information services on air quality. Documents were collected as secondary data sources (Stewart and Kamins 1999). We gathered state, regional and local air quality plans, as well as related official documents. We paid special attention to any document produced by the local air quality agencies of the four cities studied. We were specifically interested in those sections of the documents dealing with public information on air quality. We also gathered other types of documents by groups of experts and environmental associations focused on air quality information. We gathered a total of 17 documents. We also reviewed local agency websites, smartphone apps, brochures and other types of documents developed and made available by any public agency or non-governmental organization to inform the public about air pollution (**Table I**).

Analysis

All interviews were recorded and partially transcribed for subsequent thematic analysis (Braun and Clarke 2006, Fereday and Muir-Cochrane 2006). Transcripts were coded to identify recurring themes and patterns in responses. Through coding we formulated new categories and revised old ones as we read through the transcripts. Transcripts were collected for each category and subsequently analyzed in search of a description of each category, a synthesis of the evidence for each, and a global interpretation. Quotations illustrative of each concept were also excerpted. A similar process was followed in the analysis of the textual evidence.

RESULTS

Goals of communication

Many of the air quality plans and related documents consulted for this study dealt with the issue of public information. Generally, they included a section on public "information", "diffusion", "awareness" "education" or "communication". The relevance of promoting public information on air pollution was outlined in the majority of these documents. We found three main ideas relating to why public communication on air pollution is regarded as a relevant issue in air quality management. Firstly the idea that

TABLE I. THEMES AND CATEGORIES FOR THEMATIC ANALYSIS, QUESTIONS ADDRESSED AND SAMPLE EVIDENCE

Themes	Categories	Questions to be addressed	Sample evidence
Goals of the communication	The role of communication Goals of communication Current situation Challenges	How is communication with the public considered? What are the main challenges perceived?	"Information about the state of the atmospheric environment, both to the general public and between the competent bodies is another key issue for air protection policy" "From my point of view, information on air quality is being communicated poorly. It has improved over the last decade but ... "
Types of information	Air quality Air quality indexes Advisories and alerts Other Health impacts Personal actions to improve air quality Personal actions to protect oneself	What type of information is being transmitted to the public?	"We are fully aware that we lack information. Regarding air pollution we only have (on the website) information about ozone and we think it would be good if citizens could find information there on the risk of other pollutants"
Communication mechanisms	Information through the mass media Other communication mechanisms Other non-communication mechanisms	What are the current communication mechanisms? How are they perceived?	"The Air Quality Index is not normative. We are reviewing it because we believe it is confusing" "And such diffusion it is not only achieved through a website with the reference data. Warnings need to be broadcast out via far-reaching media"
Intended audience		How are the various publics considered?	"Information should prioritize the most vulnerable groups in terms of exposure to air quality"
Impacts of communication	Intended Unintended	What is the intended impact of communication? What has been achieved? What about assessment?	"The information is not reaching the public, only if there is an acute episode, if there is a controversial measure or when the annual report comes out"

communication on air pollution is required by law: many documents (and also some of the interviewees) stressed the idea that informing the public on air quality issues is required in the European and Spanish legislation. One document, for example, referring to the air pollution advisory system clearly stated that: "the main objective of this vigilance system is to meet the obligations established in Directive 96/62/CE on the evaluation and management of air quality, and Directive 2002/3/CE on ozone" (Document 9). Secondly we found the idea that communication can help reduce the health impacts of air pollution. The "Plan Aire", for instance, states that one of the main objectives of air quality management is to "convey to society that health depends, among other things, on the quality of the air" (D4). Another official document also emphasized that: "the objective of these measures is to increase information to the public, especially to vulnerable groups, allowing them to avoid exposure and to reduce emissions" (D7). Thirdly we found the idea that information can foster

public engagement in improving air quality (e.g. by influencing car-related behaviors). One document argues that:

Citizens play a key role in adopting and implementing actions aimed at improving air quality, for this reason is important to provide individuals with opportunities and information enabling them to modify their behaviour.

We found the existence of two broad conceptualizations of public communication on air pollution in the documents. Public communication seems to be associated, first, with the need to provide the minimum public information required by EU regulations; i.e. mainly information on air quality levels (through for example air quality indexes) and warnings and alerts when air pollution levels are significantly high. A second conceptualization, as found in some of the documents, considers public communication on air pollution as a broader enterprise. In the "Plan Aire",

for instance, public communication is regarded as a set of interventions under the environmental and health education rubric, aimed at promoting higher levels of public awareness and engagement in air pollution.

Challenges of communication

Only four of the 18 documents consulted discussed critically any of the general limitations and challenges facing current air pollution information systems in place in the four Spanish cities. They generally refer to the character and amount of information regarding air quality levels provided by local agencies, while also discussing some broader issues such as the role of the media, the impact of information or the vehicles for conveying this information. The "Plan Aire", for instance, refers to the lack of homogeneity and the technical character of the information provided by Spanish local agencies, and highlights the need to make this information more suited to public interests and levels of understanding. The document by the Working Group on "Información a la población en material de contaminación del aire" (Public information on air pollution) mentions the challenge of providing clear, complete, understandable and accessible information to the public, as derived from EU regulations. This document also highlights the need to go beyond the minimum information required by law and to differentiate between the various audiences (general public, interested public and affected public). From a more critical perspective, the document by the environmental non-governmental organization (NGO) "Ecologistas en Acción" (Ecologists in Action) (D1) refers to two main issues: the need to make information on air pollution more easily accessible to the general public and the need for endeavours to reach a wider audience, especially during air pollution episodes. Finally, the document by the working group on "Calidad del aire: propuestas para mejorar su evaluación y gestión" (Air quality: proposals for improving its assessment and management) questions recent criticisms of current air quality information systems which perceive them as insufficient, despite efforts by local public agencies. This report also highlights challenges stemming from what they consider to be irregular media coverage and public dissatisfaction with information on air quality.

Interviewees indicated four general challenges for public communication interventions on air pollution. Firstly, some of them considered the character of information on air quality too technical for a general audience. A local agency worker, for example, stated that "communicating with the public about

air pollution is a difficult issue" and that providing user-friendly information can be challenging (Interviewee 12). Not all participants shared this view. An NGO representative, for example, considered that the challenges facing communications on air pollution are similar to those in other environmental issues. Interviewees also referred to local public agencies' inadequate resources and skills for effective communication. Some staff members from the air quality agencies reported not having the skills needed for communicating with the public: in the words of one interviewee, "we are a very technical unit". Other interviewees stated that the dissemination of information on air quality might have potential unintended negative consequences (public alarm, habituation by the public or distrust of the agencies responsible). For example, one member of a technical unit stated: "You have to dose the level of information and media to avoid creating panic and habituation ..." (I1). Finally, some interviewees reported the belief that the low level of public awareness and use of air quality information services hinders the effectiveness of communication actions.

Communication mechanisms

The Internet has become one of the main communication channels in public air quality information services. In the cities studied, information on local air pollution was made available to the public via specific sections (environment, air quality) of city council websites. The three websites studied provided an air quality index for each of the various monitoring stations in the city. Some of these sites also provided information about pollutants and their health effects and recommendations for reducing air pollution.

The documents and interviewees consulted, generally agreed that the Internet is the key instrument for communicating with the public about air quality. Some interviewees were concerned about the need to improve existing websites (for instance, the agency responsible for Barcelona created a specific website in January 2014). Other interviewees were concerned about the accessibility of Internet services and about how easy it was for the public to understand the information provided in websites.

The mass media are regarded as another key mechanism for communicating information about air pollution to the public. Interviewees generally perceived that the mass media could significantly improve public awareness of air pollution. Public agency staff reported occasionally making use of press releases, but a general perception among interviewees was that information about air pollution

is marginally represented in the media compared, for example, to the weather. In 2011, the "Dando un respiro" (Taking a break) (D11) campaign was developed by the Red Española de Ciudades por el Clima (Spanish Network of Cities for the Climate) to increase public awareness of the impacts of air pollution on human health. To date, only two cities have implemented the campaign.

Text messages for air pollution episodes are sent in one of the cities studied. Smartphone applications (apps) are also being developed in some of these cities to inform the public about air pollution and about pollution episodes. Currently only the Madrid local environmental agency has developed an app, called "Aire de Madrid" (Madrid Air). This provides the user with geo-localized and real-time information on air pollution levels. Similar apps are being developed by other Spanish local and regional agencies and environmental NGOs (such as Calliope by Ecologistas en Acción 2013 and the Universidad Politécnica de Cataluña).

Electronic street panels have also been used for providing information on air pollution in three of the four cities under study. Some documents referred to the use of street panels as an important way of informing people about air pollution. But only one of the interviewees clearly expanded on the use of street panels as a useful channel for providing daily information on air quality levels.

Finally, we found interventions aimed at improving public understanding of air pollution that did not rely only on the passive transmission of information to the interested public via Internet or the media. Some of the cities studied have, for instance, organized educational activities, workshops and talks for the general public and students at university and high schools, and have developed educational material on air pollution. Local agencies also routinely respond to public enquiries about air pollution (**Table II**).

Types of information

We explored the content of the information on air pollution available to the public in terms of four dimensions: air quality levels, health impacts of air pollution, behaviors for reducing pollution, and behaviours for minimizing exposure to pollution.

(1) Information on air quality levels. Data about air quality levels is collected routinely from monitoring stations throughout Spanish cities, compiled and interpreted by local, regional, and state employees, and usually made freely available on the Internet. The interviewees and the documents consulted generally prioritized this type of "technical information" over others. Interviewees recognized the need to make accurate, up-to-the-minute and clear data available to the public. Two main information mechanisms are of particular importance:

i. The air quality index. Following criteria developed in other countries, the air quality index in the cities studied centres on the most important pollutants (fine particles, ozone, sulphur dioxide, carbon monoxide and nitrogen dioxide). Air pollution levels are usually banded low, moderate or high; however, each regional agency has developed its own index. The air quality index is generally provided via the websites of local environmental agencies and, in one of the cities studied, also via a specific smartphone application. Interviewees generally agreed that public communications on air pollution should be aimed mainly at disseminating the air quality index to the general public. One interviewee told us: "we use simple concepts: good, moderate, bad quality. Normal people understand this so much better. People don't understand if you say 35 micrograms. We have a code of 6 colours" (I9). However, some interviewees questioned the efficacy of current air quality indexes. Primary criticisms were related to the diversity of indexes used in the Spanish cities (lack of homogeneity), the accuracy of the banding system used to represent air quality, the retrospective character of the information provided by air quality indexes and the fact that an index does not adequately reflect chronic exposure to air pollution.

ii. Warnings and alerts are another key information mechanism in the management of air quality during pollution episodes. Warnings and alerts are provided to the general population by air quality agencies via the Internet, text messaging, the radio and, in some cities, street panels. They are aimed at reducing the impacts of high pollution levels on sensitive groups. Interviewees identified three main limitations of warnings and alerts. Some interviewees firstly highlighted the fact that alerts are provided once the episode is over. As one interviewee recognized, "you find out about it in hindsight" (I17). Other experts felt that alerts are not reaching the general population, as they are not being disseminated enough, with one interviewee concluding that "it's not a massive service". Finally, there is the

TABLE II. CURRENT PROVISION OF AIR QUALITY INFORMATION

City	Internet	Phone	Mass media	Electronic panels	Reports	Others
Barcelona	✓ City council website		✓Press releases for air pollution episodes	✓ Traffic boards during air pollution episodes	✓ Annual reports	✓Response to public enquires ✓ Public talks
Madrid	✓ City council website	✓ Texted alerts ✓ App "*El aire de Madrid*"	✓Press releases for air pollution episodes	✓Street panels ✓ Traffic boards during air pollution episodes	✓Annual reports and other studies	✓ Awareness sessions for university students ✓ Air quality workshops for the general public
Zaragoza	✓ City council website		✓Press releases	✓Street panels	✓ Annual reports	✓Educational activities
La Coruña	✓ City council website ✓ Twitter	Free phone	✓ Press releases	✓ Street panels	✓ Quarterly and annual reports	✓ Educational materials ✓ Mass media campaigns ✓Exhibitions ✓ Dissemination sessions

question of the type of information provided. Some interviewees argued that, together with the alerts, more information on actions for protecting oneself against risks from air pollution should be provided.

iii. Other vehicles include air pollution forecasts, provided in one of the cities studied but discussed only marginally by interviewees. Also, responses to public enquiries about air pollution and technical reports on local air quality, published every year by the air quality agencies, are used to disseminate information about air quality levels in the cities studied.

(2) Information on the health impacts of air pollution. Although information about the health impacts of air pollution is generally regarded as relevant in the management of urban air pollution, it seems to be less developed in the cities studied than information on air quality levels. When such information is made available it is often provided by the local public health agency, but not always linked to information regarding air quality levels (e.g. air quality indexes). The regional and local air quality plans consulted often mentioned the need to provide information concerning the health effects of air pollution. However, in two of the four cities studied, the local air quality agency websites do not provide comprehensive information on this issue. And in those websites where this information is provided, it seems to play a marginal role. We found three main beliefs among interviewees that may hinder the development of this information.

First, some experts believed that information on the health impacts of air pollution is difficult to convey to the general public, given the complexity of the impacts and associated behaviours. Second, some interviewees perceived that information about health impacts may generate public anxiety. Third, some interviewees questioned the usefulness of providing information on the health impacts of some pollutants, as they perceived that the public cannot easily avoid these impacts.

(3) Information on actions to reduce pollution. The consulted documents emphasized the need to promote individual and organizational actions to reduce air pollution levels among the population. The "Plan Aire", for example, includes a section on "information and awareness activities for improving air quality". The Barcelona Air Quality Plan "provides a set of programs, activities and resources for environmental education…with the aim of improving knowledge about environmental management in the city and fostering the engagement of residents in improving it" (D5). Also the Madrid Air Quality Plan emphasizes the need to raise awareness and engage citizens in the improvement of local air quality. The Catalan Air Quality Plan emphasizes that "Citizens play a key role in adopting and implementing actions designed to improve air quality, for this reason it is important to provide individuals with opportunities and information enabling them to modify their behavior". The local agency websites consulted usually included a section on "recommendations"

or "tips" for improving air quality in the city (public transport use, efficient driving, etc.). Two sites, for example, included recommendations about car-related behavioral changes, such as reduced driving or postponing refuelling. The interviewees generally agreed on the need to provide information on actions aimed at reducing air pollution. Two relevant beliefs regarding this expressed by the interviewees were the need to provide more positive and action-oriented messages (as opposed to frightening messages) and the need to combine these messages with structural interventions (e.g. traffic calming).

(4) Information on actions for protecting oneself against the adverse effects of pollution. The "Plain Aire" recognizes the need to improve health education concerning air pollution. Also air quality plans such as Madrid's, stress the need to identify actions for protecting the general public and, especially, sensitive groups (children, adults performing outdoor physical activities, people with chronic respiratory diseases and ozone-sensitive individuals). But information on potential actions minimizing exposure to air pollution in general seems to be very limited in Spain and only linked to specific air pollution episodes, especially involving ozone. We found very little information on this topic on the consulted websites. Among respondents, we observed differences in their views on this type of information. Some interviewees emphasized the need to provide information to sensitive groups during high pollution episodes, especially during ozone episodes, but questioned the general population's ability to avoid the risks caused by air pollution. Other interviewees, however, believed that individuals could minimize their exposure to air pollution and that public agencies should provide more information about possible coping behaviors (e.g. rethinking regular routes, avoiding exposure of children in certain areas, etc.) (**Table III**).

Intended audience

We did not find any systematic discussion regarding the intended audiences of communications on air pollution in the documents. Regarding information for increasing awareness of air pollution levels, the documents often referred to the general public as well as private organizations. Only one reference to the "interested public" was found. Regarding health protection measures, the documents and the interviewees specifically mentioned sensitive groups (generally children, the elderly and people with

cardiorespiratory problems) as the main intended audience. The Madrid Region Plan, for example, refers to the need to inform "sensitive groups: children, adults engaging in outdoor physical activities, people with chronic respiratory diseases and ozone-sensitive individuals". It is acknowledged that warnings and alerts on air pollution levels should reach the entire population, as required by the directives (alerts, for example, are aimed at "at-risk groups" when pollution is in excess of previously-announced levels and to the general population when it exceeds the alert threshold). Nevertheless, the communication of information on protective measures seems to be generally considered an issue for vulnerable groups. We did not obtain a relevant discussion on this from the interviewees.

Effects of public information actions

The impact on intended audiences of communicative interventions was considered only marginally both in the documents consulted and among the interviewees. Only three documents mentioned the outcomes of communication on air quality. For example, the document produced by the Spanish environmental NGO "Ecologistas en Acción" outlines the need for a faster and wider diffusion of warnings and alerts in order to reach the general population when air pollution levels are high. Some of the interviewees also questioned the effect, perceived as limited, of current communication actions. These interviewees were unsure that information and recommendations about air pollution provided by local and regional agencies were reaching the general population or sensitive groups. Indicators of this were, according to interviewees, the lack of public understanding of air pollution levels and the lack of response to air pollution alerts. Interviewees attributed this lack of success to current communication strategies, perceived by some as insufficient and ineffective, the lack of a broader strategy of environmental education on these issues, the need for further efforts in communication, the lack of public interest and the irregular media coverage of air pollution issues. We did not find any reference to any consideration regarding the evaluation of the effects of communication interventions.

DISCUSSION

We were interested in the main features of air quality information systems in the Spanish cities under study, as well as the main assumptions and beliefs concerning communications with the public

TABLE III. TYPES OF AIR QUALITY INFORMATION PROVIDED IN THE WEBSITES OF THE FOUR CITIES

	Information on air quality levels	Information on health impacts	Information on actions to reduce air pollution	Information for protecting oneself from pollution
Madrid	Air Quality index (AQI) Type of pollutants, sources Air pollution forecasts Maps Satisfaction survey	Health impacts by pollutant	Information about car-related behavioral changes and residential energy consumption	No
Barcelona	AQI Sources Maps	Health impacts by pollutant	Recommendations on car-related behavior	Brief recommendations on exposure
Zaragoza	AQI Forecast Sources Maps	No	No	No
La Coruña	AQI Forecast Maps Survey on satisfaction with information provided	No	Recommendations on car use, public transport and refuelling	Brief recommendations on exposure

held by those involved in the management of air pollution. Previous studies have focused primarily on the technical characteristics of air quality information (Van den Elshout 2008, Shooter and Brimblecombe 2009, Wartenberg 2009, Plaia and Ruggieri 2011, González Ortiz 2013), as well as on the reception of information by the public (Beaumont *et al*. 1999, Bush *et al*. 2001, Johnson 2012) and its attitudinal and behavioral effects (Evans *et al*. 1988, Skov *et al*. 1991, Stieb *et al*. 1995, Johnson 2003, Semenza *et al*. 2008, Wen *et al*. 2009, Sexton 2011). But very few studies have explored the main characteristics and assumptions underlying air quality information systems.

In the past two decades, significant advances have been made in the development of public information services on air pollution in the four Spanish cities studied. Promoting public awareness on air pollution is now regarded as an important issue for air quality management, which could be attributed, in part, to the need to implement EU and national regulations. The system of advisories and alerts is well established, and more emphasis is being placed on improving air quality indexes, providing improved localized and real-time information on air quality, and improving the vehicles via which this information is conveyed. Public information is regarded as a crucial issue in air

quality management, but local and regional agencies have tended to focus on the technicalities of information and have given limited attention to ensuring that this information is relevant to the general public.

Much progress is still to be made. The air quality information systems in the cities in this study seem to be focused more on providing the information required in the legislation than on engaging with the public. Current air quality indexes, advisories and alerts, and web-based information about air pollution provided by the responsible agencies potentially contribute to public awareness of air pollution. But there are still many questions that remain to be answered. For instance, who are the target audiences of air quality information? Is the goal the protection of vulnerable individuals' health or reducing overall pollution exposure? Or is it the promotion of more sustainable behavior (e.g. more sustainable car use)? Does this information match public requirements? Is it having any effect on the public? A lack of knowledge and sensitivity on these topics, together with a lack of the resources and skills needed for effective risk communication and the existence of certain beliefs and assumptions about the role of communication interventions in attitudinal and behavioral change, may hinder potential progress in this area.

Implications and recommendations

How can public information services on air quality be improved? Traditional answers to this question have focused first on the need to provide more information about air pollution to the public. Social research (Hedges 1993, Bush *et al*. 2001) has documented low levels of public awareness on air pollution and information services in various contexts. Thus, increasing the amount of information available to the public may be a first step. A second step may be to improve the content and presentation of information on air quality. Social research has suggested that the public does not find the information provided by air pollution services to be useful (Hedges 1993, Beaumont *et al*. 1999, Bush *et al*. 2001). Potential strategies in this sense include adjusting air quality data to the personal or health interests of individuals at the locations where they live, improving air quality indexes with bandings or indices linked directly to information on health effects, developing more effective messages, generating information tailored to specific individual needs and developing more appealing web pages and smartphone apps (Beaumont *et al*. 1999, Johnson 2003, Van den Elshout *et al*. 2008, Shooter and Brimblecombe 2009, Wartenberg 2009).

From a social and behavioral science perspective, however, these two solutions rest on an oversimplified view of attitude and behavior formation. Shooter and Brimblecombe (2009), conclude that the "apparent reluctance of the public to react to air pollution and modify their behavior" is the direct result of a "poor performance by the air quality indexes". But this affirmation shows a clear ignorance of previous research on the attitudinal and behavioral effects of communication on air pollution (Evans *et al*. 1988, Skov *et al*. 1991, Stieb *et al*. 1995, Henry and Gordon 2003, Johnson 2003, 2012, Neidell 2006, Semenza *et al*. 2008). The provision of effective information can be considered a prerequisite for promoting reduction and avoidance behavior among individuals, and some studies have shown evidence of its positive impacts (Skov *et al*. 1991, Neidell 2006). But information alone does not guarantee attitudinal and behavioral changes (Johnson 2003), given that a complex set of interrelated internal and external barriers may moderate its effects. Some such factors found in the literature are, for instance, public distrust of information (Hedges 1993, Beaumont *et al*. 1999, Bush *et al*. 2001), the use of sensory and health cues (Johnson 2012), levels of risk perception (Bickerstaff 2004, Claeson *et al*. 2012), familiarity with the health effects of air pollution (Stieb *et al*. 1996), and individuals' habits and routines.

Thus, besides improving the content of information on air pollution, we find of particular importance the development of a more systematic and evidence-based approach to communications on air pollution. This means, in our view, dedicating time and effort to integrating the findings of social and behavioral research into air quality management, and to clarifying the goals of communication, understanding the range of interventions available, and designing, implementing and assessing these interventions adequately.

The first question to be considered is the goal of air quality information. In our study, we found only one report that systematically evaluated the state of public information on air pollution. With the publication in 2013 of the "Plan Aire" by the "Ministerio de Agricultura y Medio Ambiente", the need to go beyond the provision of information and to progress towards a more systematic approach to risk and health communication on air pollution took on new importance. In order to minimize the health effects of air pollution the plan aims to foster behavioral changes in individuals through environmental and health education interventions. As we see it, there are still a number of internal barriers to incorporating this systematic and evidence-based approach into public air quality information service, but the publication of the "Plan Aire" may be a step towards this end.

In our view there are two spheres of activity where communication strategies on air pollution should improve in the coming years: public engagement and behavioral change. Regarding public engagement in air pollution issues, previous studies (Bush *et al*. 2001, Wartenberg 2009, Vallejos and Oñate 2013) have outlined the need to develop alternative strategies for providing air quality information that involves the public. And a number of research and engagement initiatives have been developed in recent years in various countries aimed at incorporating the views and needs of local communities into air pollution information management (Cole *et al*. 1999, Lambert *et al*. 2006, Yearley 2006). The main idea underlying these studies is that air pollution services, still based on the "top down" information deficit model ("keep it simple and the public will grasp the message"), could benefit from consulting the public about their needs and expectations at both national and local levels (Bush *et al*. 2001, Payne-Sturges *et al*. 2004). Community-based participatory research (O'Fallon and Dearry 2002, Conrad and Hilchey 2011) and "participatory sensing" (Goldman *et al*. 2009, Paulos *et al*. 2009),

based on the fact that the public can now objectively record, analyze, and discover a variety of patterns regarding important issues in their lives, such as the quality of the environment, offer promising strategies for fostering public engagement in air pollution issues.

But protection from the risks of air pollution should not only rely on involving the public in environmental assessment and decision-making. Urging individuals to reduce pollution and protect themselves from the risks of air pollution should be, together with regulatory measures (stricter air quality standards, etc.) and structural changes (traffic calming, etc.), one of the key goals of urban air quality management. Insights from the social and behavioral sciences have provided a good level of understanding of the determinants and processes of individual and population-level change in the areas of sustainable behavior and health promotion, as well as on potential interventions for changing behavior (Merzel and D'afflitti 2003, Grier and Bryant 2005, Wilson and Dowlatabadi 2007, Abroms and Maibach 2008, Steg and Vlek 2009).

These studies have potential implications for communications on air pollution that have not been systematically taken into account. Some of our interviewees, for example, claimed that air pollution services should rely more on the media. But the claim that the messages conveyed through the media would have an impact on members of the public exposed to them is regarded as too simple (Scherer and Juanillo 2010), and several other factors must also be considered, such as the individuals' motivations, habits and routines and the existence of external barriers to behavioral modification. Another implication relates to the type of interventions that air quality agencies should promote. Public air pollution information services clearly stress information-based interventions. But, as research suggests (Mckenzie-Mohr and Smith 1999, Stern 2000 for studies on sustainable behavior, and Scherer and Juanillo 2010 for health communication), when the desired behaviour (e.g. avoiding polluted streets, car-related behavioral changes, etc.) involves several internal and external changes, the intervention needs to combine various strategies such as prompts, face-to-face communication, effective messages, telephone health programs, social norms, social support, etc. The reaction of individuals to air pollution is more complex than it is often assumed, thus any attempt to produce significant changes in perception and behavior should take all of the above into account.

Limitations

We acknowledge some limitations of this study. Firstly, although we gathered evidence from various stakeholders and included workers from different agencies, we did not include experts with identical profiles from the four cities. Second, we did not analyze in depth the specificities of air quality information (air quality indexes, advisories and alerts and other types of information) provided by local and regional agencies. We recognize that the technical characteristics of the information provided are a relevant issue in communicating with the public, although we consider this to be beyond the scope of our analysis.

CONCLUSION

In order to reduce the health effects of air pollution, European cities will have to implement a set of evidence-based regulatory, structural and behavioral interventions. The aim of this paper has been to explore the current air quality information systems in place in four Spanish cities, as well as to understand the ideas and assumptions driving these systems. We have analyzed the main features of public information on air pollution, explored its limitations and the factors that may contribute to these limitations, and provided some suggestions on how best to address them. Communications on air pollution would ideally incorporate findings from the social and behavioral sciences, as these may aid in the design and evaluation of more holistic and effective interventions aimed at protecting the public. We hope this paper will contribute to a wider consideration and discussion of the issues involved in communicating with the public on air pollution.

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