Science of the Total Environment 621 (2018) 886–894

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Understanding social and behavioral drivers and impacts of air quality sensor use☆

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ARTICLE INFO

Article history:
Received 16 August 2017
Received in revised form 7 November 2017
Accepted 24 November 2017
Available online xxxx

Editor: P. Kassomenos

Keywords:
Air pollution
Social science
Citizen science
Monitoring
Exposure

ABSTRACT

Background: Lower-cost air quality sensors (hundreds to thousands of dollars) are now available to individuals and communities. This technology is undergoing a rapid and fragmented evolution, resulting in sensors that have uncertain data quality, measure different air pollutants and possess a variety of design attributes. Why and how individuals and communities choose to use sensors is arguably influenced by social context. For example, community experiences with environmental exposures and health effects and related interactions with industry and government can affect trust in traditional air quality monitoring. To date, little social science research has been conducted to evaluate why or how sensors, and sensor data, are used by individuals and communities, or how the introduction of sensors changes the relationship between communities and air quality managers.
Objectives: This commentary uses a risk governance/responsible innovation framework to identify opportunities for interdisciplinary research that brings together social scientists with air quality researchers involved in developing, testing, and deploying sensors in communities.
Discussion: Potential areas for social science research include communities of sensor users; drivers for use of sensors and sensor data; behavioral, socio-political, and ethical implications of introducing sensors into communities; assessing methods for communicating sensor data; and harnessing crowdsourcing capabilities to analyze sensor data.
Conclusions: Social sciences can enhance understanding of perceptions, attitudes, behaviors, and other human factors that drive levels of engagement with and trust in different types of air quality data. New transdisciplinary research bridging social sciences, natural sciences, engineering, and design fields of study, and involving citizen scientists working with professionals from a variety of backgrounds, can increase our understanding of air sensor technology use and its impacts on air quality and public health.

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1. Introduction

Rapid developments in technology are fueling an influx of handheld, wearable technologies (e.g. smartphones, activity tracking devices, heart monitoring) engineered to collect real-time, localized data about individuals and their immediate surroundings. One increasingly relevant example of these technologies is low-cost, portable air quality sensors. The rapid and decentralized evolution of these technologies has resulted in a variety of affordable sensors with different mechanisms for data collection (Fig. 1) that have uncertain data quality, measure

☆ The research described in this article has been reviewed by the National Health and Environmental Effects Research Laboratory, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the agency, nor does the mention of trade names of commercial products constitute endorsement or recommendation for use.

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https://doi.org/10.1016/j.scitotenv.2017.11.275
0048-9697/Published by Elsevier B.V.

Fig. 1. Low-cost sensors (highlighted in green) provide a wide variety of modes of data collection, including hand-held devices, backpack units, wearable devices, indoor and outdoor fixed devices, and community sensors such as the Village Green sites (https://www.epa.gov/air-research/village-green-project). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

different air pollutants, and possess a variety of design attributes, including how readings are presented or interpreted (See Jiao et al., 2016 and Lewis et al., 2016 for recent performance evaluations of low cost sensors). The developers of these technologies are varied, including traditional air measurement technology companies, crowd-funded start-ups, large information technology (IT) corporations, and community organizations. While this technology is proliferating, research to inform the translation of air sensor data into information that might guide an individual's decisions about daily activities remains limited. Despite these uncertainties, the potential demand for sensor technology is high, driven by widespread concern about air pollution as well as an interest in reducing personal exposure. The adoption of low-cost air quality sensors by both public and private sectors, for a diverse set of applications, portends expansive use and widespread circulation of sensor-based air quality data. Further research is needed to elucidate how air quality sensors and their data are being used and to better understand the groups and individuals who use them.

To fully grasp the potential impact of the ubiquitous availability and public use of air pollution sensor technology it is important to understand 1) how communities of sensor users grow and are sustained, 2) the drivers behind individual and community-level air sensor use and data collection, 3) the behavioral, socio-political, and ethical implications of introducing sensors into communities, 4) how sensor data is communicated within and across communities, and 5) how crowdsourcing capabilities can be harnessed to achieve greater benefits of community sensor networks. Gaining understanding in these areas will require application of social science theories and methods. Currently, there are few studies that evaluate social or economic implications of low-cost air quality sensors (Zappi et al., 2012; Bales et al., 2014; Willett et al. 2010). A recent article reviews the use of community-based participatory research (CBPR) approaches to study air pollution in communities (Commodore et al., 2017). However, the article focuses on communities as researchers, and sensors as objects of research, rather than on the motivations for non-research use of sensors or the social context of introducing sensor technologies into communities. Theories of risk governance (the process by which decisions about risk are determined) and responsible research and innovation provide useful context for considering how the development of air quality sensors and their subsequent introduction into communities can impact individual and group level decisions (van Asselt and Renn, 2011; Owen et al., 2012). There are well established health risks from exposures to air pollution (U.S. EPA, 2009; U.S. EPA, 2013) that can potentially be mitigated through use of air quality sensors, and also potential risks to health and community welfare that can arise from the introduction of sensors into communities, for example if poor quality data leads to behaviors that increase exposure. Government processes that shape policy for new technology determine the potential action pathways for groups (such as non-governmental organizations or community groups) and individuals. Conversely, individual and group interactions with new technology, from the initial introduction of an innovation to relegation of obsolete technologies to marginalized communities, often influence the policy process. Vulnerable or overburdened communities that face multiple social or environmental stressors may have different responses to new technologies and the interpretation of expert versus local knowledge (Corburn, 2005). Experts are defined here to be individuals with formal education and professional experience in a relevant scientific field. Citizen scientists are members of the general public (not professional scientists or analysts) who are involved in scientific research and activities (Cohn, 2008; Silvertown, 2009). Citizen scientists and engaged community members with local knowledge often engage in scientific studies or analyses using scientific methods or local experiential knowledge to better understand local environmental conditions and risks (Aoki et al., 2017). Both experts, citizen scientists, and engaged community members contribute to the overall understanding of environmental quality and risks in local communities. Better understanding of the effects of such a knowledge-enabling technology as air quality sensors, particularly when adopted by communities vulnerable to marginalization (communities with low access to resources, opportunities, and agency) can lead to identification of opportunities for collaborative policy solutions and reduced environmental health burdens. The process of engaging in monitoring of local air quality conditions can help to increase environmental literacy in communities and build capacity of communities to engage both in partnering with academic researchers, and in developing local actions to reduce air pollution exposures and improve public health.

In this commentary, we discuss the limited literature on application of the social sciences in the area of air quality sensors. We identify opportunities for interdisciplinary research that brings together concepts and methods from a range of social science disciplines with environmental science, engineering and user interface (UI)/user experience (UX) design communities that are developing, testing, and deploying air quality sensor technologies. We lay out the nature of the challenges associated with sensor data generation, interpretation, and analysis. We identify opportunities for collaboration with communities and organizations to better understand how and why sensors are being used, and how technological innovations may be able to improve the ability of communities and individuals to reduce exposures to air pollution and improve individual and public health.