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Citizen science and environmental justice: exploring contradictory outcomes through a case study of air quality monitoring in Dublin.

Abstract

Citizen science is advocated as a response to a broad range of contemporary societal and ecological challenges. However, there are widely varying models of citizen science which may either challenge or reinforce existing knowledge paradigms and associated power dynamics. This paper explores different approaches to citizen science in the context of air quality monitoring in terms of their implications for environmental justice. This is achieved through a case study of air quality management in Dublin which focuses on the role of citizen science in this context. The evidence shows that the dominant interpretation of citizen science in Dublin is that it provides a means to promote awareness and behaviour change rather than to generate knowledge and inform new regulations or policies. This is linked to an overall context of technocratic governance and the exclusion of non-experts from decision-making. It is further closely linked to neoliberal governance imperatives to individualise responsibility and promote market-based solutions to environmental challenges. Last, the evidence highlights that this model of citizen science risks compounding inequalities by transferring responsibility and blame for air pollution to those who have limited resources to address it. Overall, the paper highlights the need for critical analysis of the implications of citizen science in different instances and for alternative models of citizen science whereby communities would contribute to setting objectives and determining how their data is used.

Keywords: citizen science, air pollution, environmental justice, political ecology

1 Introduction

Citizen science is advocated as a response to a broad range of contemporary societal and ecological challenges. This is based on its various perceived advantages including improving the availability and quality of data, shifting scientific inquiry towards greater engagement with contemporary societal and ecological challenges and helping to overcome a supposed crisis of legitimacy on the part of experts and scientific knowledge (Davies 2018; Strasser and Haklay 2018; Oliver 2019). Citizen science has accordingly been adopted across different sectors of environmental management and planning including climate change, conservation, biodiversity monitoring, water and air quality amongst many others (Silvertown 2009).

However, there are widely varying models of citizen science which may either challenge or reinforce existing knowledge paradigms and interrelated power dynamics (Irwin 1995; Ottinger, 2017). There are indications that, in certain cases, the embrace of citizen science may be interrelated with neoliberal approaches to environmental management (Kimura and Kinchy 2016). This paper is generally situated within the critical environmental justice and political ecology literatures which have highlighted the limits of dominant responses to environmental challenges (Castree 2008) and critiqued the dominance of technocratic, depoliticised approaches to environmental management (Forsyth 2008; Holifield 2015; Swyngedouw 2010). It applies these perspectives to interrogate citizen science as it is carried out in the context of a major environmental health issue, that of urban air pollution.

The overall aim of this paper is to explore the relationship between citizen science in the context of air quality monitoring and environmental justice, which is achieved through a case study of citizen science air quality monitoring in Dublin, Ireland. The corresponding objectives are, first, to characterise the dominant model to citizen science in Dublin, second, to explore to what extent this could lead to substantive improvements in air quality management, third, to identify the logics underpinning the adoption of citizen science initiatives, and, last, to investigate to what extent citizen science might help to address or, alternatively, to compound inequalities associated with air pollution.

To achieve this, the paper first discusses inequalities associated with urban air quality and their links to technocratic models of expertise. It subsequently discusses conflicting interpretations of citizen science including both previous radical examples which have emerged in the context of environmental justice struggles and seemingly distinct approaches associated with the uptake of citizen science by state agencies. The empirical sections of the paper then present a case study of air quality management in Dublin, Ireland, and the role of citizen science therein. The evidence shows that the dominant interpretation of citizen science in Dublin amongst air quality managers is that it provides an effective means to promote awareness and behaviour change rather than to generate knowledge and inform new regulations or policies. This is linked to an overall context of technocratic governance and the exclusion of non-experts from air quality management. It is further closely linked to neoliberal governance imperatives to individualise responsibility and promote market-based solutions to environmental challenges. Last, the evidence highlights that this model of citizen science potentially compounds inequalities by seeking to transfer responsibility and blame for air pollution to those who have limited resources to address it.

2 Air quality and environmental justice

According to the World Health Organization (2016), an estimated three million deaths annually are caused by poor ambient (outdoor) air quality. In Ireland, it is estimated that there are approximately 1,600 premature deaths each year linked to air pollution, primarily due to fine particulate matter and nitrogen dioxide from home heating and the transport sector (European Commission 2017). It has also been estimated that the risks posed by Covid-19 are compounded by poor air quality (Cullen 2020). In addition, while the European Union sets out legal limits for air quality through the Clean Air for Europe Directive and the World Health Organization provides its own (more stringent) guideline levels, it is widely recognised that for many major pollutants, there are no safe thresholds below which significant health effects do not occur (Barnes et al. 2014).

The burden of air pollution is unevenly distributed, both globally, and within countries in the Global North (Véron 2006; Graham 2015) and has thus been analysed as a question of environmental justice (Chakraborty 2009). Studies have shown that exposure to air pollution is closely linked to issues such as poor housing conditions, proximity to polluting facilities and road infrastructure and by extension, to questions of class and racial inequality (Corburn, Osleeb, and Porter 2006; Buzzelli et al. 2003). As noted by Beattie, Longhurst, and Woodfield (2002, 2473), "air quality is poorest in more economically deprived areas where the health status of the resident population may also be relatively poor". This is equally the case in Ireland where, according to a European Environment Agency report (2018, 20) "analysis of air pollution and

hospital admissions for cardiovascular and respiratory diseases identified higher mortality risk among those from lower socio-economic groups".

There are also important inequalities associated with dominant responses to air pollution. These include awareness campaigns that seek to promote behaviour change which, it has been argued, seek to transfer responsibility for managing air pollution and associated health risks to those least able to address them (Hubbell et al. 2018; Monahan and Mokos 2010). Furthermore, research has demonstrated that such awareness campaigns have also had limited success in substantively reducing air pollution (Pearce, Kingham, and Zawar-Reza 2006; Bickerstaff and Walker 2002). Further responses to air pollution include technical and fiscal measures such as congestion charges and promoting the uptake of electric vehicles which equally raise important equity issues associated with the additional financial burden they impose on, for example, lower-income people with older and more polluting vehicles (Charleux 2014).

There are substantial uncertainties associated with air pollution including the challenge of understanding localized variations and the risks encountered in everyday life, what Buzzelli (2008, 503) terms the "microgeographies of human exposure". In addition, there are important issues surrounding the measurement and production of knowledge about air pollution that directly connect with inequality and power. For example, according to Graham (2015, 194), "technical, depoliticised, medicalised, positivist, physical geographic and public health policy discourses still overwhelmingly dominate [this] field". Such perspectives are associated with a lack of attention to the specific circumstances of vulnerable populations which may contribute to their levels of exposure (such as housing conditions) and to the dismissal of information which

they provide (Ottinger 2010). In general, such depoliticised perspectives contrast with an understanding of air pollution as a fundamentally economic and political question in the sense that it is bound up with established patterns of fossil fuel-based economic growth, transport and urban development, to which exposure is mediated by existing forms of inequality and powerlessness (Buzzelli 2008; Carmichael and Lambert 2011).

One response to these challenges has been to suggest the adoption of citizen science approaches to monitoring air pollution (Commodore et al. 2017). The following section provides an overview of citizen science and different models thereof before we move on (in Section 4) to discussing how this has been applied in the context of air quality management.

3 Citizen science

A general definition of citizen science is provided by Ottinger (2017, 351) as referring to the involvement of "individuals without formal scientific credentials… in knowledge production activities". Citizen science has historically been associated with fields such as ornithology and astronomy where researchers have used volunteers to collect and sometimes analyse large volumes of data (Bonney et al. 2009; Dickinson, Zuckerberg, and Bonter 2010). It has now come to be applied across a wide variety of fields including monitoring water and air quality, biodiversity and conservation, amongst many others (Conrad and Hilchey 2011). There are a wide range of perceived, and sometimes contradictory, benefits which differ depending on the priorities of the observer (Kimura and Kinchy 2016). Related to this there are different models of citizen science varying from those which enrol volunteers in projects directed by credentialed

scientists and follow established scientific methods, to those undertaken by social movements to challenge official narratives and progress environmental justice campaigns (Ottinger 2017).

One important model of citizen science, which has historically arisen in the context of environmental justice campaigns, is that described by Ottinger (2017, 351) as "social movement-based citizen science". This closely relates to the definition of citizen science provided by Irwin (1995, 111) as "a form of science developed and enacted by citizens themselves" which "refers to the types of knowledges developed by citizens to counter official accounts". An emphasis on opposition to official, 'expert' models of knowledge is echoed by Scott and Barnett's (2009, 374) description of the role of 'civic science' within environmental justice struggles as "a resource to support oppositional strategies of environmental movements". As apparent here, a key aspect of this model of citizen science is that it is directed and carried out by communities in opposition to the state and/or other powerful interests. It further typically involves the development of critiques of existing models of knowledge production and the institutional structures within which they are embedded, or what Irwin (1995, 133) terms the "knowledge-authority structures of modernity". Last, in such contexts, knowledge production is not an end-in-itself, but rather a strategy which can be used to draw attention to an issue, mobilise a community and/or create pressure on regulators to take action (Ottinger 2017).

In contrast to the above, Ottinger (2017, 352) identifies an alternative model of "scientific authority-driven citizen science", wherein the research objectives are set primarily by professional scientists corresponding to the imperatives of their scientific field. In such contexts, non-professionals contribute by acting as voluntary research assistants. According to Ottinger

(2017), there are fundamental conflicts between the theories of change guiding this model of citizen science and that grounded in social movement organising. Specifically, the scientific-authority model approach assumes a linear relationship between "better information and better decisions" (Ottinger 2017, 359). It generally identifies knowledge, rather than power and/or collective action, as the key prerequisite for social change. There is thus typically an assumption that the generation of data will unproblematically translate into more stringent policies and/or more pro-environmental individual behaviour and choices, including amongst citizen scientists themselves.

It has been argued that the prominence of the scientific authority-driven approach to citizen science can be connected to the impact of neoliberalism on research practices and environmental management, and that this leads to contradictory and problematic outcomes (Liévanos, London, and Sze 2011). As noted by Lave (2012, 28), citizen science projects "provide vast amounts of unpaid work for physical scientists", which is especially valuable in the context of fiscal austerity and diminished research budgets. The scientific authority-driven model, particularly insofar as it aims to change individual behaviour, has also been linked to neoliberal imperatives to individualise responsibility for the management of environmental problems. For example, in their discussion of citizen science approaches to monitoring water quality, Monahan and Mokos (2010, 22) describe how "people are expected to "responsibilize" to gain awareness of existing dangers or threats and mitigate their own (potential) exposure." This can be criticised for ignoring the social and structural constraints on people's choices and behaviours and for shifting attention away from the need for collective responses to environmental problems and (e.g. Shove 2010).

4 Citizen science and air quality management

As noted above, it is widely suggested that citizen science methods could be applied to address air quality challenges, including by generating new knowledge on localized risks, promoting social and cultural change and facilitating collective action by exposed communities (Commodore et al. 2017; Pritchard and Gabrys 2016; Van Brussel and Huyse 2019; Hubbell et al. 2018). Projects invoking citizen science ideals are also being implemented by regulators and local governments. For example, 20,000 people participated in the 'CuriouzeNosen' (Curious Noses) project supported by the Flanders Environment Agency project in Belgium, which sought to measure nitrogen dioxide from transport and gather new information about the severity and distribution of air pollution (Fritz et al. 2019; Van Brussel and Huyse 2019). In Ireland, the Clean Air Together citizen science project, run by the Irish Environmental Protection Agency (EPA) will involve distributing 1,500 low-cost 'diffusion tube' sensors to the public, also with the objective of measuring traffic-related nitrogen dioxide levels (EPA 2020).

The contrasting models of citizen science outlined in Section 3 above are equally reflected in the context of air quality monitoring, with many examples of scientific authority-driven citizen science approaches to monitoring air quality. For example, there are various studies which suggest that the role of non-professionals should be to gather air quality data in the context of projects designed and directed by researchers or other experts (e.g. Mahajan et al. 2020). According to Commodore et al. (2017, 378), citizen science in the context of air quality monitoring is "a process whereby citizens are involved in science as researchers", which

contrasts with the oppositional model of citizen science and its emphasis on challenging established methods of scientific research described above. This literature also suggests that the advantage of citizen science in the context of air quality management is that it could promote increased awareness and behaviour change including steps to reduce one's exposure to air pollution as well as one's contributions to it (Hubbell et al. 2018).

In contrast, there are important examples of social movement-based citizen science relating to air pollution including the 'bucket brigades' in the Southern USA. These were community groups which used low tech systems to assess air quality and challenge information put forward by regulators and polluters (Ottinger 2010). Although described using the terminology of 'coproduction' rather than citizen science, another notable campaign documented by Corburn (2003) identified how the housing and employment conditions of low-income and minority groups in New York led to increased exposure to air pollution. Further important examples are described by authors including Yearley et al. (2003) and Pritchard and Gabrys (2016). In terms of their organisation, these projects have generally been initiated and directed by community groups, albeit in some instances with technical and logistical support from universities or NGOs (Commodore et al. 2017). Within this framework, the objectives often relate to obtaining recognition for the validity of information generated by communities and pushing the state to regulate for substantive improvements in air quality.

Overall, the preceding review has highlighted the existence of significant challenges and inequalities associated with the management of air pollution, to which citizen science has been proposed as a possible response. However, it has also been demonstrated that there are

competing models of citizen science which involve different and contradictory objectives and are linked to different social forces. For example, it has been suggested that the uptake of citizen science may, in some instances, be linked to neoliberal imperatives to cut research and/or regulatory costs or individualise responsibility, and thus that citizen science may have "an ambiguous relationship with justice" (Kimura and Kinchy 2016, 348). With a small number of exceptions (e.g. Liévanos, London, and Sze 2011), these issues have not been subject to in-depth empirical investigation. In response, the overall aim of this paper is to explore the relationship between citizen science in the context of air quality monitoring and environmental justice, which is achieved through a case study of air quality management in Dublin, Ireland, and the role of citizen science therein.

5 Methods

This paper draws on a case study of air quality management in Dublin, Ireland focusing on the function of citizen science within efforts to address air pollution in the city. Air pollution has been recognised as an important environmental health problem in Dublin since at least the mid-1980s at which point there was severe pollution arising from the use of bituminous or 'smokey' coal for home heating (Brady 1986). Due to rapid economic growth and urban sprawl in the 1990s and early 2000s, there was growing awareness of the implications of increasing car use for air quality (Dublin City Council 2007). These problems have not been resolved and there are currently severe issues associated with air pollution in Dublin arising from both the transport sector and the use of solid fuel for home heating. The transport sector, particularly diesel vehicles, are a key source of both nitrogen dioxide and fine particulate matter (PM2.5) (DCCAE,

2017). Solid fuel use contributes to increased levels of both fine and coarse particulate matter (PM2.5 and PM10) and is the leading contributor to levels of PM2.5 across Ireland (EPA 2019a). In Dublin, there have been repeated breaches of World Health Organization guideline levels for particulate matter and a recent breach of EU limit values for nitrogen dioxide (DECC 2020).

A range of measures have been introduced or are under consideration to address these issues. These include proposals for the introduction of congestion charges (Corrigan, 2019), and initiatives aimed at behaviour change such as a Dublin City Council website which provides real-time air quality information to the public and aims to enable individuals to minimise risks to their health.[1] Further market-oriented and behaviour change initiatives include attempts to promote awareness of the air quality implications of solid fuel use and encourage retrofitting domestic heating systems, and the Irish government's policy to promote mass uptake of electric vehicles. The government's Climate Action Plan (2021), for example, includes a target of nearly a million private electric vehicles on the road by 2030 which is seen as a response to both climate and air quality challenges. There have also been recent steps to address knowledge gaps through increasing the number of stations in the air quality monitoring network (EPA 2017). These include fixed-site monitoring stations managed by the Environmental Protection Agency (EPA) plus additional indicative air quality monitors managed by Dublin City Council. An outline of the case study area including the location of air quality monitoring stations is included in Fig.1 below.

[1] https://dublincityairandnoise.ie/

Last, there has been a series of citizen science projects involving air quality monitoring. These include projects coordinated by the Environmental Protection Agency (EPA), the national agency responsible for monitoring and managing air pollution with support from An Taisce, an environmental NGO (Clean Air Together, GLOBE, Clean Air@School), and projects coordinated by university researchers (iSCAPE, WeCount). The analysis in this paper focuses on exploring the logics and implications of these projects within the overall context of air quality management in Dublin. The case study presented below encompasses all the aforementioned projects which are jointly explored in the analysis. This approach, of choosing Dublin, rather than an individual citizen science project as the case study, was adopted primarily because most interviewees had been involved with multiple citizen science initiatives and typically did not clearly distinguish between them in their responses to interview questions. Thus, the case study aims to provide an overall picture of the role of citizen science in air quality management in Dublin.

The research is based on a mixed-methods approach including 20 semi-structured qualitative interviews with ten professionals involved in facilitating and managing citizen science projects and ten volunteers who were involved in data collection.[2] The professional interviewees included staff in the regulatory agency with responsibility for monitoring air quality at national level (the Environmental Protection Agency), officials in local and national government (Dublin City Council and the Department of Environment, Climate and Communications) and staff in an

[2] The study was given ethics consent by the Faculty Research Ethics Committee of [anonymised for review] on behalf of the European Commission (FET 20.02.034). All subjects have provided informed consent either in writing or verbally.

environmental NGO. All these interviewees had been involved in facilitating or managing one or more of the aforementioned citizen science projects, albeit with varying levels of involvement. These interviewees were initially recruited using a purposive sampling approach which involved identifying key figures in relevant organisations. The sample was then expanded using a snowball sampling approach whereby each interviewee was asked to provide the name of further relevant contacts until no new suggestions were being made (Atkinson and Flint 2001). The interview questions covered the interviewees' roles within air quality management in Dublin, their assessments of specific citizen science projects with which they had been involved and their general perspectives regarding the value and/or disadvantages of citizen science including the validity of the data which is generated.

The volunteers who were interviewed comprised those participating in an ongoing university-led citizen science project which the authors of the paper were coordinating (XXXX).[3] This approach was chosen for pragmatic reasons due to the difficulty of contacting volunteers in other projects which had concluded by the time the research was taking place. The interview questions covered participants' views regarding air quality issues, primarily in their local areas, prior experiences of engaging with policymaking in relation to air quality, their experiences thus far with the specific project in which they were participating and what participants hoped to achieve through taking part in a citizen science project. It should be acknowledged that there are limits to the representativeness of this sample due to it being comprised of citizen science participants volunteering in the context of one specific university-led project. This is partly mitigated by the

[3] Project title anonymised for review

fact that four out of ten participants had taken part in previous citizen science projects and could also speak about their experiences of these. In addition, it is notable that the university-led project was at a relatively early stage of realisation at the time the interviews took place. Related to this, the interviews focused to a much greater extent on participants' concerns regarding air quality and their aspirations for what citizen science data could contribute to its management, rather than on interviewees' experiences of one specific project.

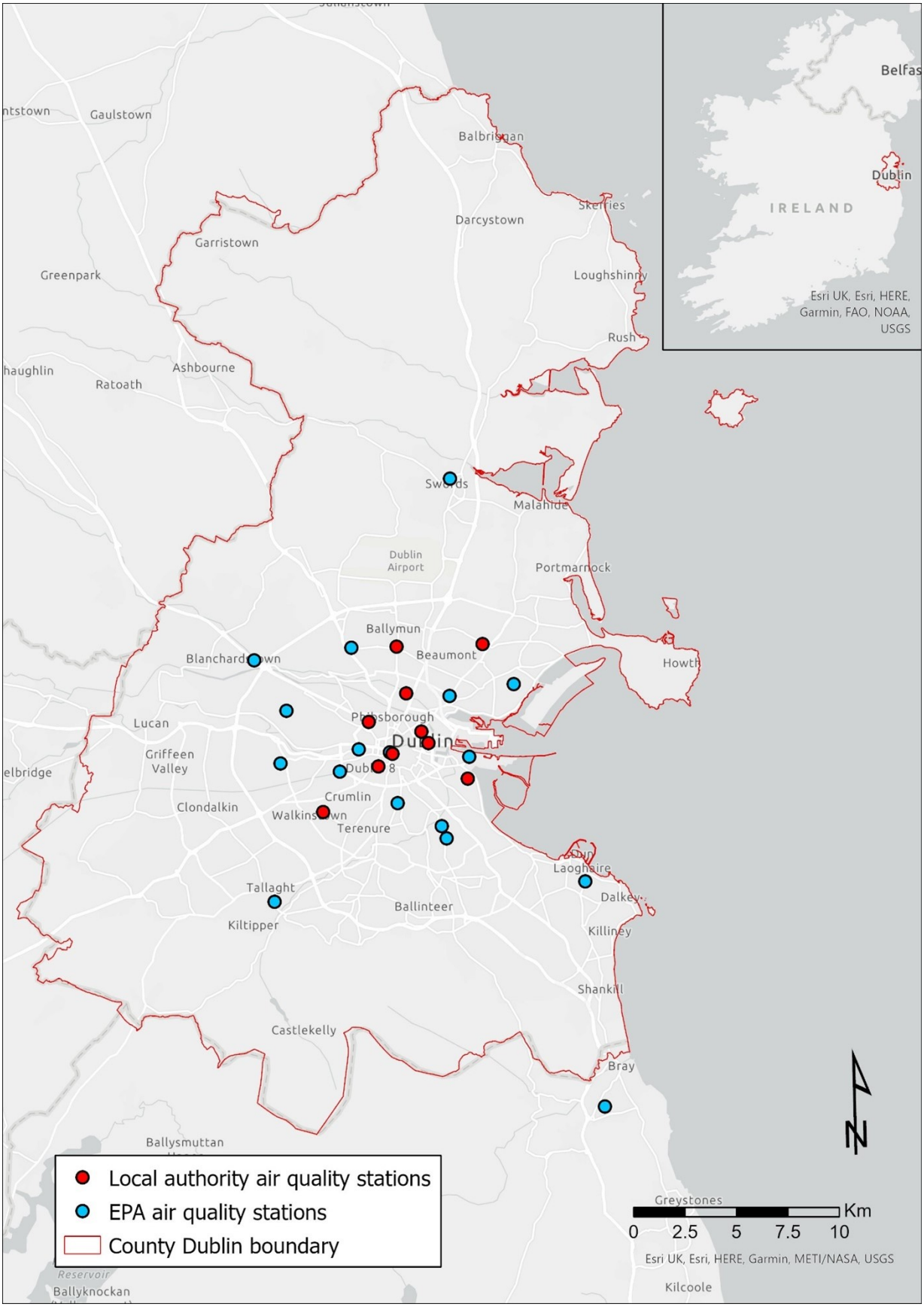
To supplement the evidence derived from the interviews, the analysis draws on documentary sources, primarily policy documents and reports (46 in total) produced by state agencies. Relevant documentary sources were selected by searching for all documents dealing directly with air pollution and citizen science in Ireland produced by government sources and NGOs over the past 10 years. These were used to gain an understanding of the policy context but also served to corroborate some of the key themes identified in interview data, such as a focus on behaviour change in air quality policy, and thus have essentially been used for triangulation.

All of these sources, including both interviews and documentary sources, were analysed by the lead author using NVivo and following a hybrid inductive-deductive method which allowed themes and issues to emerge from the data in an inductive manner but was framed by an overall set of concerns related to the objectives of the study (Flick 2018). The coding followed two stages involving, first, preliminary coding of the substantive topics of discussion and, second, building themes and relating these initial simple codes to the conceptual focus of the research.[4]

[4] The authors can provide copies of the codebook and interview guide upon request via email to the corresponding author.

Quotes from interviews and documents have been included in the empirical sections of the paper, primarily where this helps to illustrate one of the core themes of the paper. This is not necessarily related to the number of times a given idea was raised in interviews.

The following sections of the paper provide an analysis of the case study oriented around the paper's objectives. Thus, Sections 6 and 7 explore competing models of citizen science in Dublin, Section 8 identifies challenges to translating citizen science data into practice and Section 9 jointly discusses connections between neoliberal logics and citizen science and consequent environmental justice issues.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Loughshinny
Rush
Ashbourne
Ratoath
Swords
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Ballinteer
Killiney
Shankill
Castlekelly
Bray
Ballysmuttan
Greystones
Kilcoole
Ballyknockan
Local authority air quality stations
EPA air quality stations
County Dublin boundary
N
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Esri UK, Esri, HERE, Garmin, METI/NASA, USGS

Figure 1. The case study area and location of air quality monitoring stations.

6 Participants' objectives: trust in data and the politics of air pollution

We present evidence here regarding the objectives of those participating in citizen science as volunteers. Such interviewees typically described their objectives as related to gathering data to secure new regulations and measures to improve air quality. One key objective was the installation of more EPA air quality monitoring stations, which was linked to a perception that citizen science data might not be as reliable or be taken as seriously as that provided by 'official' monitoring stations. Further objectives included securing reductions in volumes of traffic in their local areas, improvements in infrastructure surrounding schools, restrictions on heavy vehicles and improvements to public space and walking and cycling facilities. As such, these were collective or state interventions rather than being related to behaviour change. In general, and with some exceptions, these interviewees' contributions reflected an assumption that the information collected would translate in a relatively straightforward manner into new policies because the authorities would take note if there was sufficient reliable data. Thus, there are parallels with the scientific authority model of citizen science described by Ottinger (2017, 359) in the sense of an assumed linear relationship between "better information and better decisions".

On the other hand, there were alternative perspectives whereby participants provided both a critical analysis of existing air quality monitoring practices and identified political barriers to the translation of citizen science data into better regulation of air quality. This is best illustrated by

struggles surrounding air quality in Ringsend in Dublin, where one citizen science project participant was both a resident and a member of the 'Ringsend Environmental Health Group', a community group concerned about the impacts of industrial development in their predominantly working-class area. In particular, the group is concerned about air pollution linked to the recent construction of an incinerator and associated increased heavy goods vehicle traffic, alongside emissions from other existing industries in the area. In addition, there are fears that this is not being adequately monitored (see also Whelan 2018). This is illustrated by the following quote from the relevant interviewee:

> *Monitoring the air quality really should be done where people are breathing the air… They've now installed PM2.5 monitoring in the recycling centre, which will never go in the red purely because of where it's sited, you know what I mean?*

Generally, this participant suggested that political considerations influence the location of monitoring stations and that they are strategically placed to reduce the possibility of exceedances, thus suggesting that official air quality monitoring should not be regarded as definitive or unbiased. This is contrary to perceptions of professionals and air quality managers regarding the reliability of the official network which are discussed below. Notably, this closely parallels the understanding of environmental knowledge as socially constructed provided by citizen science theorists such as Irwin (1995). It illustrates an oppositional form of citizen science which is concerned with the contestation of official processes of knowledge production.

However, the same interviewee also noted there would be significant political barriers to securing investment in additional monitoring due to the same political considerations regarding the siting of monitoring stations. In fact, this interviewee described having participated in a previous citizen science project in Dublin run by an environmental NGO which had indicated exceedances of air quality limits but noted that these had never been further investigated. This argument generally reflects the fact that those using citizen science methods in ways which are oppositional to powerful bodies such as the state and/or industry, face challenges linked to inequalities of knowledge, resources and power (Ottinger 2010) which present obstacles to the translation of citizen science methods into substantive air quality improvements. It further highlights the need to consider the steps, beyond simply generating data, whereby citizen science data can be leveraged. As described by Pritchard and Gabrys (2016), this could include using data to mobilise a community, initiate conversations with regulators and generally build political pressure for new regulations or policies.

On the other hand, these critical perspectives were held by a small minority of citizen science volunteers (two interviewees). It is worth noting that this may be linked to the management of the citizen science projects investigated which were all primarily directed by either state agencies or professional researchers. It seems logical that those with more critical perspectives might avoid participating, for example if they (understandably) assumed that the projects would be unlikely to challenge official narratives regarding air pollution in Dublin.

7 Professional perspectives on the value of citizen science

In contrast to the perspectives of project participants, there was considerable scepticism on the part of professional interviewees about the validity of citizen science data amongst professional interviewees and air quality managers. This was due primarily to a lack of trust in the low-cost monitoring technologies used in citizen science initiatives, such as diffusion tubes used to measure nitrogen dioxide, as well as concern that participants had undue faith in these technologies. This is illustrated by the following quote from a local government official:

> *The people who engage in that think, you know, I am a citizen scientist, I am producing data and my data is as valid as your data. And great if it was, I would be delighted if it was but it's not necessarily always the case.*

This is important because, as argued by Dorfman et al. (2006), the perceptions of air quality managers regarding non-expert knowledge largely determine what efforts are made to facilitate citizen input and integrate it into decision-making. In addition, while it is the case that not all data generated by citizen science is correct, there are many documented examples where citizen science initiatives have provided valuable data that was not available through other means, both in the specific field of air quality monitoring (Yearley et al. 2003) and in other areas of environmental research (Crall et al. 2011; Kremen, Ullman, and Thorp 2011).

In addition, the scepticism with which citizen science data was received contrasted with the perceived reliability of the official fixed-site monitoring stations run by the EPA and local government. This is illustrated by the following quote from a local government official:

> *It's just using a sensor, a Raspberry Pi or something you can buy on the internet that would give you an indication. It's not in any way comparable to the fifty thousand euro air quality monitoring instrument that we have here which uses radioactive elements for measurement of really accurate particulate levels.*

While there is a recognition here that citizen science data can provide an indication of air pollution levels, the situation is generally similar to the citizen science project discussed by Gabrys, Pritchard, and Barratt (2016, 11) where both "both monitoring instruments and citizen-gathered data were questioned by regulators" which the authors attribute to a "clear power dynamic… around who might be authorized to undertake environmental monitoring".

Related to the scepticism regarding the validity of citizen science data, amongst professional interviewees the key benefit of citizen science projects was perceived to be its potential to increase awareness of air pollution and, by extension, to contribute to behaviour change. This focus on individual behaviour is illustrated both in policy documents and also in the following quote from a local government official:

> *The real benefit of citizen science is how do you influence behaviour. Because at the end of the day, while local and national governments can do X amount in terms of air quality, a lot of it will come down eventually to personal choice and behaviour.*

In this context, citizen science was generally understood to complement existing strategies to disseminate information, increase scientific literacy and alter behaviour in relation to both

transport and, particularly, home heating and solid fuel use. In the literature, such initiatives are often described as following the 'deficit model' of communication and behaviour change, which assumes that problematic or risky behaviours are due to insufficient scientific literacy and information. However, the validity of this model is generally thought to be limited. There is evidence that similar approaches to managing air quality, and other environmental challenges, have had little success in other contexts because they often fail to address social and structural determinants of behaviour (Bickerstaff and Walker 2002; Blake 1999; Irwin; 1995; Owens 2000; Pearce, Kingham, and Zawar-Reza 2006).

The scepticism towards citizen science data and emphasis on behaviour change is further notable because it represents a shift away from the scientific authority-driven model of citizen science as defined by Ottinger (2017) in the sense that the emphasis amongst professionals was not on the collection of bigger datasets and more information. Likewise, at least amongst professional interviewees, there was little expectation that data would translate into new regulations or policies. Instead, such aspirations, which are already a simplification, have been almost wholly displaced by an emphasis on behaviour change. On this basis the approach apparent here could arguably be described as a distinct 'behaviour change model' of citizen science because, unlike the scientific authority-driven model, it is not primarily concerned with the collection of more or better data.

8 Expert knowledge and the scope for citizen science to influence air quality management in Dublin

As stated above, an important objective of this paper is to investigate the scope for citizen science to contribute to effective and environmentally just air quality management. The following section explores a key aspect of the context for citizen science in Dublin which emerged from the analysis, namely an overall technocratic and managerial approach to managing air pollution. While it has already been demonstrated there is scepticism about the validity of citizen science data amongst professional stakeholders, the evidence further suggests that this scepticism is related to an overall technocratic air quality management system in Dublin wherein only specific forms of knowledge are regarded as valid within the policy-making sphere.

More specifically, the analysis demonstrates that there is a high level of reliance on forms of knowledge which are gathered using official monitoring techniques and expensive monitoring technologies and which accord with narrowly defined institutional guidelines. This is associated with the key role of standards set by the EU in determining whether action is taken in relation to air pollution (even though these standards are regarded as relatively lax and are significantly less stringent than those set by the World Health Organization (Williams and Carslaw 2011)). As described by a government advisor, the primary focus is on ensuring that legal limits set by the EU are not exceeded, rather than on preventing health impacts:

> *There's no real incentivization to do much. Even though we might have statistics showing that there are health impacts and premature mortality at the current exposure level so that there is a rationale to do something, but because the legislation is framed this way, and because the focus of government is very much on legal compliance, particularly with EU legislation. And that's what's prioritised.*

As indicated here, there are strict protocols regarding how exceedances of EU limit values are monitored and validated which, by extension, determine what forms of evidence are regarded as valid. This is clearly illustrated by issues surrounding the uptake of data generated by air quality modelling. Specifically, there are recognised knowledge gaps associated with local air quality in Dublin including a lack of understanding of localised variations in exposure (McNabola, Broderick, and Gill 2009; Broderick et al. 2015). One proposed means to address this is to carry out additional air quality modelling to provide a more fine-grained understanding of local air quality between fixed monitoring stations. Up to the present, some air quality modelling has occurred in Dublin via short term projects involving collaboration between regulators and academic researchers but there is no ongoing modelling programme (e.g. Aves and Williams 2019).

However, even those projects which have taken place have not translated into efforts to reduce air pollution. For example, recent modelling projects have indicated that there are likely exceedances of EU limit values of nitrogen dioxide at various sites in Dublin along major roads (EPA 2019b) but, because these have not been recorded by a fixed-site air quality monitoring station run by the EPA, these exceedances are not regarded as valid and there is no requirement for further action. This differs from other European countries, such as the UK, where modelling is regarded as a sufficient basis to identify problem sites and take regulatory action (Yearley et al. 2003; Borrego 2015). In the following quote (from the transcript of a parliamentary debate), the exclusive reliance on specific monitoring techniques is connected to an overall unwillingness to take concrete action to improve air quality:

> *We do not need to get official notification that the air quality in our cities is poor. We know that for a fact. What we are seeing is an avoidance by government of its responsibilities in that it is waiting for the EPA to install monitors, review them and then produce the proof that the limits are being exceeded* (Humphreys 2019).

This quote thus identifies a distinction between facts which are regarded as self-evident and/or 'common sense' and those which have institutional and scientific backing. There are also clear connections with Ottinger's (2010) argument that air quality monitoring standards and protocols present important barriers to non-expert actors and those who do not have access to expensive monitoring technologies. This is further important because this overall focus on scientifically validated data likely provides the backdrop for the scepticism regarding citizen science data discussed above.

Corresponding with this overall reliance on expert knowledge, there are few opportunities for public engagement with planning and policymaking in relation to air quality. There is no requirement for public consultation on the preparation of air quality management plans in Ireland, which contrasts with the UK system where public consultation on air quality management plans has been a statutory requirement since the mid-1990s (Dorfman et al. 2006). Likewise, interviews with citizen science volunteers demonstrated a strong shared feeling that there are insufficient opportunities for communities to influence how air pollution is managed. For example, speaking about their general experience of campaigning to improve air quality in

their local area, one interviewee (who was also a citizen science volunteer) described the situation as follows:

> *If you are asking whether we feel listened to, the answer is no.*

9 Citizen science, neoliberal logics and environmental (in)justice

A core objective of this paper is to investigate the implications of citizen science from an environmental justice perspective. A further related objective, which is also addressed in this section, is to explore the relationship between the adoption of citizen science and neoliberal imperatives, including towards the individualisation of responsibility for environmental management.

Neoliberal logics related to individualising responsibility and promoting market-based solutions are apparent in the sphere of air quality management in Dublin and are, arguably, an underlying factor driving citizen science projects. For example, in the context of transport, one citizen science project, which was managed by the EPA and an environmental NGO and carried out in collaboration with local schools, involved an objective to encourage parents to "adapt their choice of transport for bringing children to school as a result of increased awareness" (EPA 2020, 17). However, options in terms of making 'responsible' transport choices are circumscribed by social class and income, amongst other factors. For example, in recent years, a key thrust of both air quality and climate policy in Ireland has been the promotion of electric vehicles which are represented as a 'sustainable' transport choice (e.g. DECC 2019). This is a

classic neoliberal environmental policy in the sense that it centres 'sustainable' consumer choices as a key response to environmental challenges (Klein 2015). As is often the case, such choices are to be encouraged through various means including awareness and educational campaigns (of which citizen science is one aspect) as well as financial incentives (state subsidies). Similar to other behaviour change campaigns, this neglects the social and structural constraints on behaviour, most notably that, despite some state subsidies, electric vehicles remain unaffordable for the vast majority of people (McCurry 2021). Meanwhile, electric vehicles are also tied to new forms of extractivism and green colonialism in the Global South associated with the impacts of lithium mining (Willis 2019). In general, the construction of sustainable transport as a 'choice' minimises wealth disparities and associated constraints on behaviour. This implicitly blames those unable to afford electric vehicles as responsible for air pollution and also deflects attention from the need for more widely accessible sustainable transport options, for example, improved public transport and walking and cycling infrastructure.

The aspiration to promote behaviour change in relation to home heating and solid fuel use through citizen science initiatives also has problematic implications from an environmental justice perspective. It was frequently suggested by professional interviewees that the primary advantage of citizen science is creating awareness of the problematic effects of solid fuel use and contributing to behaviour change. This positions solid fuel use not as a necessity but rather as a matter of individual choice, with problematic 'choices' arising from a lack of information and awareness. It is important to note that, in certain contexts, solid fuel burning is not driven by necessity (Pearce, Kingham, and Zawar-Reza 2006) and rather represents what Malm (2021, 88) describes as "luxury emissions", referring to those which derive from upper-class consumption

habits and should be regulated out of existence. Echoing this interpretation one interviewee described the use of solid fuel in Dublin as "leisure burning".

However, even if behaviour change was an effective strategy to address such luxury consumption, there is evidence that this interpretation does not apply to Dublin. Specifically, there are acute problems of fuel poverty in Ireland which are linked to an estimated 2,800 excess deaths each year (Zeka et al. 2014), and solid fuels (primarily coal) are particularly relied upon by those in fuel poverty for financial reasons (Kerimray et al. 2017). Reliance on low quality polluting fuels is especially prevalent amongst some of the most marginalised sections of Irish society such as Irish Travellers, primarily due to poor quality housing (National Traveller MABS 2019). In addition, there are very significant costs associated with switching fuels or retrofitting one's home and such steps are inaccessible to lower-income communities in Ireland due to insufficient state support (Social Justice Ireland 2020). Retrofitting and fuel switching are also typically not a possiblity for those living in private rented accommodation (SVP and Threshold 2021). Thus, similar to the case of electric vehicles, an emphasis on awareness and behaviour change unfairly stigmatises such groups for their presumed 'choices' or 'lack of awareness' and deflects attention from the need for comprehensive, affordable retrofitting programmes.

10 Discussion and conclusions

Alongside the general uptake of ideas regarding collaborative environmental management (Dorfman et al. 2006), citizen science has been embraced by regulators and other state agencies involved in managing air quality. However, there are very distinct models of citizen science. Linked to this, it has been suggested that certain forms of citizen science may have problematic

implications from an environmental justice perspective and ultimately reflect neoliberal environmental management logics (e.g. Kimura and Kinchy 2016). In response, the aim of this paper has been to explore the relationship between environmental justice and citizen science approaches to monitoring air quality through a case study of Dublin, Ireland.

The first major objective of this paper has been to characterise the dominant model of citizen science in Dublin. The analysis has shown varying understandings of what citizen science is and should be, with key differences identified between citizen science volunteers and professionals. Amongst volunteers, objectives included securing direct interventions to improve local air quality. In some cases, this was underpinned by a belief that data would translate relatively seamlessly into such interventions corresponding to the scientific authority-driven model of citizen science and associated theories of change outlined by Ottinger (2017). Amongst a small number of citizen science volunteers, there were more critical perspectives which challenged official narratives regarding air quality, highlighting political factors underpinning current monitoring practices and political barriers to translating citizen science data into practical action. However, this was a minority perspective which is potentially due to some degree of self-selection amongst volunteers. In contrast, the dominant perspective on citizen science in Dublin, in the sense that it was shared by professionals with most power over how citizen science data is interpreted and applied, was that its primary objective should be promoting awareness and behaviour change. This was associated with scepticism about the validity of data generated by citizen science methods. It contrasts with the scientific authority-driven model of citizen science in the sense that it does not prioritise data collection and/or knowledge production. It could

perhaps be described as comprising a distinct 'behaviour change' model of citizen science which differs from those hitherto identified in the literature.

A further related objective of the paper was to explore the scope for citizen science to lead to effective approaches to managing air pollution. The evidence shows that the dominant model or interpretation of citizen science as related to behaviour change and an associated scepticism regarding the validity of citizen science data, presents important challenges to this. The scepticism regarding the validity of citizen science and barriers to its translation into practice data can further be contextualised as linked to overall reliance on expert knowledge gathered using narrowly defined monitoring systems and technologies. Overall, citizen science has not provided a means to overcome these obstacles and contribute to more collaborative environmental management as has been suggested in the literature on this topic (Commodore et al. 2017). In addition, while there has not yet been research specific to Dublin or Ireland on the effectiveness of behaviour change interventions in relation to air quality, international experience suggests that these are unlikely to translate into substantive improvements (Bickerstaff and Walker 2002; Blake 1999; Owens 2000).

The paper's third major objective has been to explore the logics underpinning the adoption of citizen science initiatives. Through the literature review it emerged that neoliberal environmental governance logics are a key factor driving the update of citizen science in various contexts (Kimura and Kinchy, 2016), and we thus investigated their role within the case study. The evidence suggests that neoliberalism is in fact an important logic underpinning the adoption of citizen science initiatives in the context of air quality management in Dublin. Contrary to

suggestions in the literature, citizen science did not represent a response to reduced budgets for research and/or environmental monitoring, which relates to the fact that data collection was not prioritised as an objective. In contrast, neoliberal imperatives related both to the individualisation of responsibility for managing environmental problems and in favour of market-oriented solutions emerged as a core underlying logic. Specifically, citizen science projects were framed as a means to educate and spread awareness about air pollution and promote behaviour change, especially in relation to transport and home heating. This is linked to aspirations to promote change in individual consumption patterns and advance green consumerism, such as through encouraging the purchase of electric vehicles. As discussed below, this arguably compounds environmental injustices through diverting attention from the broader social and structural influences and constraints on behaviour including wealth, housing standards and access to public transport infrastructure, over which the state exercises significant control. Overall, it can be conceptualised as an aspect of the neoliberal project to downplay the significance of collective action in response to environmental problems and shift responsibility from the state towards individuals and markets (Holifield 2004).

A final objective of this paper has been to explore to what extent citizen science might help to address or, alternatively, compound inequalities associated with air pollution. First, it is worth highlighting that the (in)effectiveness of citizen science is closely tied to issues of inequality. This is because, although there is no recent research on inequalities of exposure to air pollution in Dublin, it is likely that this follows the typical pattern whereby air pollution disproportionately burdens those suffering other forms of deprivation including poor quality housing and low income (Véron 2006; Graham 2015). The lack of meaningful action to address air pollution,

including a lack of attention to the evidence generated by citizen science projects, means that these groups will likely face ongoing harm. Conversely, the evidence shows that the dominant responses to air pollution in Dublin, including the behaviour-change model of citizen science, risk compounding inequalities by seeking to place the responsibilities for, and costs of, addressing it upon those with the least resources to do so. Specifically, the emphasis on individual awareness and behaviour change stigmatises those who may be using the only mode of transport available to them or heating their home using the only fuel they can afford.

The above discussion leaves obvious questions regarding what might constitute alternative, more effective and equitable approaches to citizen science. Existing literature on this topic highlights that many important examples of citizen science in the context of environmental struggles which have been initiated by communities without the involvement of researchers and/or state agencies. One conclusion from this paper might be that researchers should simply support such campaigns if and when they arise, for example by using their institutional position to amplify the voices of participants and by finding ways to put their skills and resources at the services of these movements. However, there is likely also scope for more collaborative approaches facilitated by researchers and regulators, given the challenges faced in community campaigns with interpreting data and gaining acceptance for its validity (Ottinger 2016, 2010). Collaborative approaches would require the involvement of communities in setting objectives and determining how their data is used. Further, it would likely require support with interpreting data and identifying how it could be used most effectively in the context of existing institutional frameworks and policies. In general, while this paper has provided a critical assessment of current citizen science efforts, there is scope for communities equipped with new monitoring technologies and supported by researchers to challenge official narratives and management strategies regarding air quality and

push for more effective and equitable approaches. Further research should investigate what strategies have been and could be used to achieve this.

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