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Citizen as Sensors' Commitment in Urban Public Action:
Case Study on Urban Air Pollution

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ABSTRACT

Based on a case study in Rennes, the article presents how a group of urban public actors re-uses methods and technology from citizen sciences to raise the urban air quality issue in the public debate. The project gives a group of inhabitants the opportunity to follow air quality training and proceed PM2.5µm measurements. The authors question the impact of the ongoing hybridisation between citizen science and urban public action on participants' commitment. The authors present how the use of PM2.5-sensors during 11 weeks led to a disengagement phenomenon, even if the authors observe a strong participation to workshops. These results come from an interdisciplinary methodology using observations, interviews, and data analyses.

KEYWORDS

Air Quality Sensors, Citizen Participation, Citizen Sciences, Commitment, Metrology

INTRODUCTION

The fast and widespread use of smartphones emerged when urban public actors, such as local authorities and urban administrations, realised the possibilities of changing citizen participation. Research in urban sociology analyses the impact of information and communication technologies (ICTs) on participative democracy and urban e-governance: some authors note in particular a transcription for digital technologies of some classical civic tools, like participatory budgeting, collaborative maps, and public debate platforms (Douay 2016; Ottaviano 2015). This digital adaptation benefits the change of scales – geographic scale, time scale, number of participants, etc. –, characteristic of ICTs. It enhances the possibility to produce and to share urban data on the field.

Other uses of digital technologies, especially mobile technologies, are observed and involve citizen participation: crowdsourcing, voluntary geographic information, citizen sciences (See et al. 2016). Some convergence points appear between citizen participation organized by cities on environmental issues and citizen sciences approaches.

In this paper, we study the effect of the ongoing hybridisation between a citizen science project and urban public action on the commitment of participants in a citizen-sensor-network project based on a case study in Rennes (France). By hybridization we mean the exchange of modality of participation, like the task or purpose that a resident has to do to be considered as a member of the participative process. In the case of citizen-sensor-network studied, the main modality of participation was sensing the air. How did local authority become an organizer of citizen metrology and how was

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the participant's experiences affected? How were the sensors used in a metrology project, whose main objective is not the creation of knowledge but education?

Firstly, we review literature on citizen participation and metrology and we propose an analytical framework of commitment based on Thévenot's theory (Thévenot 2006). Next, we describe the case study on urban air pollution and the political issue that induced a municipality to make a citizen metrology project, and we present the city's expectations of the participants' contributions. Then, we present the plurality of the participants' commitment during the project and the difficulties to keep participating due to technical failure and misunderstanding of the purpose of the project. Finally, we show how the data set produced by the participants can be used to study the practices of citizen metrology.

LITERATURE REVIEW

Rick Bonney (Bonney 1995) defined citizen sciences as scientific methods that involve non-scientists. Another definition of citizen sciences was given by Alan Irwin (Irwin 1995) and refers to the democratisation of science and citizens' relations with science governance. In both cases, the public participates in a collective action including field observation, inventory, and metrology that describe the urban environment and spur discussions. With the rise of low-cost air pollution sensors (Kumar et al. 2015), and the *citizen as a sensor utopia* – in other words, the possibility to create a network of a six billion humans using ICTs to measure and to share situated knowledge with the aim to create a common good (Goodchild 2007) – citizen metrology becomes a suitable way of action for cities.

Environmental metrology aims to quantify chemical components, species, among other attributes of the environment to describe and study phenomena. Metrologies are structured by methods and protocols recognized by scientific communities. Metrology is sometimes used by citizens to produce street science in local communities when environmental controversies emerge (Corbun 2005). Those citizen metrology projects can be managed by scientist-activists (Topçu 2008).

The number of alternative metrologies on air pollution that are outside of an institutional framework and without certified experts for monitoring air quality is increasing in Europe – e.g. Montre verte, Mobicitair, Ambassad'air in France; Smartcitizen in Spain and in the Netherland; Luftdaten in Germany; Bruxsel'air in Belgium (ADEME et al. 2017). There is a large scientific literature on sensors and data quality, such as sensitivity of the sensors to varying environmental conditions (Broday & Citi-Sense_Project_Collaborators 2017), and measurement bias, such as the impact of siting on data (Morawska et al. 2018; Miskell et al. 2017). We noted that the bias due to the use by non-expert has not been studied, although the large widespread use of air quality sensors has increased the number of citizen-sensor-network projects. The ethnomethodology, initiated by H. Garfinkel, shows how non-experts define specific strategies, techniques and methods, called ethnomethods, when they have to proceed with some tasks (Garfinkel 1967). The research related to this paper aims to show the existence of ethnomethods in a citizen-sensor-network community, that we name alternative metrology. Other studies focus on the use of low-cost sensors to enhance air quality models to provide insights into patterns of pollutant emissions (Popoola et al. 2018), to enhance measurement errors in epidemiological studies (Jerett et al. 2017), and to produce information for heath applications (Huck et al. 2017).

In this paper, we present a case in which low-cost air quality sensors are used in urban public action by local authorities with the participation of citizens. This institutionalization of alternative metrology takes part in an ongoing phenomenon of sharing practices between citizen science and citizen participation led by local authorities. V.M. Eitzel (Eitzel et al. 2017), for example, mentions the case of the city of Boulder (US), which organized citizen science projects to enlist residents in the development of an urban resilience strategy. Our case study, the Ambassad'air project of the City of Rennes (France), provided a group of residents in two urban districts with air quality training and gave them 2.5μm particulate matter sensors during the wintery pollution periods. The main objective

of the project was to alert the general public to environmental health issues through peer education. This approach is close to awareness and information campaigns in the context of health democracy, with the intent of increasing individual responsibility on health issues (Hache 2007). In our case study, the creation of new knowledge on air quality was secondary for local authorities.

Analytical Framework

A number of authors study citizen participation in science projects looking at the integration of the citizen to knowledge creation during the research project (Haklay 2015; Houllier 2016). This framework is similar to Arnstein's ladder (Arnstein 1969), which comes from studies in urban planning and citizen participation. The ladder is composed of eight levels of citizen participation defined by organizer's intention: *manipulation*, *therapy*, *informing*, *consultation*, *placation*, *partnership*, *delegated power* and *citizen control*. The main difference is that the scale's integration is based on the decision-making process in a context of participatory democracy. The hybridisation of the project between citizen science and citizen participation in public action makes the usual analytical frameworks on participation hard to use, because the purpose of the participation and the objectives of the project were unclear and not shared by all the members. As an alternative to measuring citizen participation with Arnstein's ladder or a similar theoretical framework, we focused on the commitment of the volunteers during the project, and not on the influence they had in regard to the purpose of the project.

The notion of commitment covers a wide range of definitions, including: the implication in a common cause, the obligation bound to a promise, and the way people are bound to a project or a situation. Using Ervin Goffman's microsociology, Howard Becker formalized an analytical framework for this notion in the 1960s (Becker 2006). He defined commitment as a side-bet made in another situation before the action, which must be respected by a person in order to keep the coherence of his behaviour in the ongoing action.

For Laurent Thévenot (Thévenot 2006), people are made of several commitments, which are combined and mixed in time and space. With the notion of regime of commitment (*régime d'engagement*), the sociologist considers the variability of behaviour during the action to adapt to the material environment and to the behaviour or actions of other people. He draws up a typology of commitment to make the distinction between the regime of familiarity (*régime familier*), the regime of regular action (*régime du plan*) and the regime of public justification (*régime de justification publique*). The regime of public justification describes the commitment, in which an actor justifies his or her action by their participation in a common good and by following principles and values. The regime of familiarity describes the commitments that come under routines, habits, and personal actions. In the regime of regular action, the actor is considered as a rational, autonomous from and unattached to their environment, whose commitment to a common action aims to realise their own agenda. With this framework, the sociologist shows that a commitment depends on a person's capacity to coordinate with other actors and with their environment during an action.

Case: Air Pollution Issue and the City's Action

The Ambassad'air project in Rennes was supported by a large range of stakeholders, including: the municipality, several local associations dedicated to environment protection and digital education, the air quality monitoring authority (AASQA), called Airbreizh for the Brittany Region, and the French Environment and Energy Management Agency (ADEME). In this section describing political science concepts and environmental issues, we present the context of air quality issues in France and the response of the City of Rennes with citizen metrology.

A Growing Preoccupation for Urban Air Pollution and the Obligation for the City to Act

The medical community agrees that air pollution has substantial effects on health. Since 2013, the World Health Organization (WHO/Europe 2013) classifies outdoor air pollution as a leading environmental cause of cancer deaths. The consequences can also be daily discomforts and illnesses,

severe diseases of the respiratory system, the cardiovascular system and related organs. Urban air pollution, and in particular PM_{10} and $PM_{2.5}$, became a public health problem, and awareness campaigns are regularly carried out. During the Ambassad'air project, a short training was given to the participants by a local expert on air quality monitoring. He presented on the physical and chemical aspects of air pollution, monitoring protocols, and health risks. To describe the risks, the expert used striking numbers:

Just some figures to visualize them better. In France, it is said that 48,000 people die prematurely. I am not saying that they died of air pollution. A premature death due to air pollution. The European Commission refers to 700,000 people in Europe… It is also said that, depending on the cities, pollution within cities can reduce the life expectancy from three to eight months.

This number of 48,000 deaths is frequently reported by the media. It comes from a study published in 2016, led by the French National Public Health Agency – Santé Publique France (Bourdillon 2016). It is usually associated with the cost of air pollution, estimated at 101,3 billion euros per year in France by a parliamentary inquiry committee (Commission 2015). Those impressive human and financial costs put the urban air pollution issue at the top of environmental priorities in the public debate.

According to the health and environment service of the City of Rennes, this international and nationwide coverage has had an impact on the risk perception among citizens. Information requests made by citizens have increased and the issue of air quality has appeared in urban planning processes and in consultation meetings. An actor summarized, "There is no complaint, but preoccupations definitely increase".

This increasing public debate on the health environmental issue takes part in a large policy transformation on outdoor air quality. The evolution of public instruments has changed with the enlargement of targeted pollutants sources, enabled by the development of measurement networks associating metrologists and epidemiologists (Lascoumes 2007). The main sources of pollution have been emissions from industrial activities. For those pollutants, the strategy used by public policy is to reduce emissions with technological improvement, and to isolate the sources of emissions. Nowadays, they are still monitored, but ordinary emissions from transport and domestic heating systems, are also considered important pollutant sources. Controversies on diesel use for car engines show the limits of technological improvement strategies. Other modes of action have been experimented with by citizens. It can be restrictive regulations, like urban congestion charges, or mobilisations and information, as in our case study. This evolution of policy is also a result of the transposition of the European directive from 1990 into the French law, the "Loi Barnier" (1995). It established the participation principle, which stipulates that every citizen has the right to access environmental information.

In this context of public health concerns, cities remain in a leading position to act. Since 2016, the City of Rennes and the organization for environment and consumption in Rennes (MCE) have been acting on urban air quality with citizen metrology. The purpose is to measure the 2.5µm particle matter levels on two districts, with a fleet of mobile sensors. The project, named Ambassad'air, takes part in a voluntarist policy led by a group of municipal councillors. They chose to fight against urban air pollution by mobilising inhabitants, instead of directly running a restrictive policy. Originally, the aim was for citizen monitoring to "change behaviour" and push stakeholders to act on this health environment issue. This method embodies the hypothesis expressed by the political scientist F. Boutaric (Boutaric 2014), on the evolution of French public policies on urban air pollution:

[…] Public action wants to question citizens in order for them to adapt their behaviour to imperatives regarding air quality improvements – due to the multiplicity of stakeholders, to the difficulties of acting at different scales, to the weights added by economic actors, who are in position to get their points of view and interests across. (Boutaric, 2014, p.15)

Soon after the beginning of the project, the expectation of the city changed: the main goal was to give participants the role of air quality ambassadors who are in charge of sensitising their relatives, their colleagues, and their neighbours.

Citizen Metrology or City Metrology: A Fragile Balance Between Public Action and Citizen Sciences

Using citizen metrology is not common for local authorities. The measurement process is a tool to describe the environment used by scientists and experts. It is also a tool for environmental policy; guideline values, warning levels, critical thresholds are fixed by regulation to evaluate and define objectives. The French regulation follows the European Union directive (2008), which defines WHO recommendations as an objective. To perform this kind of policy, common protocols and metrology conventions have to be established (Desrosières 2008). An expert has to be authorized to proceed with the certified measurements. In France, the AASQA is devoted to this mission at the regional level. This accredited metrology gives decision makers the possibility – and the obligation due to national law and EU-directives – of acting on a short-term scale, such as instituting alternate traffic procedures, and through long-term actions, like urban planning guidance. With the mandatory disclosure of the environmental data, citizens have access to the measurement values produced by the AASQA. However, measurements are difficult to interpret, to verify or to contest for those who do not know the techniques and methods. The ATMO scale, created in 2004, transcribes the measurements of four pollutants (O_3, SO_2, NO_2, PM_{10}) into one value between 1 and 10, from "very good" to "very bad". The daily worst pollutant-level defines the ATMO. Unlike the PM_{10} level, the $PM_{2.5}$ level is, however, just informative and not yet restrictive. The ATMO aims to inform, and takes part in the emergency air quality alert for pollution events. Nowadays, this strategy is controversial because some epidemiological studies show that long-term exposure to a middle-high background pollution level is more harmful than punctual and short peaks. In this situation of uncertainty, discussions on public action strategies and on technical democracy arise (Callon et al. 2001).

Technological evolution has enabled the development of low-cost sensor networks. One consequence is an important increase in alternative metrology. This practice comes from activist circles, who use it to put institutional metrology to the test when sociotechnical controversies appear. It is currently being adopted by other publics (Chateauraynaud & Debaz 2013). Those citizen networks belong to a field of citizen science defined by Alan Irwin (Irwin 1995). Linda Carton and Peter Ache (Carton & Ache 2017) analyse two citizen-sensor-networks in the Netherlands that use sound metrology and seismic metrology to protest against public action. They argue, in particular, that it has a strong impact on local environmental governance by creating a boundary-object (Star & Griesemer 1989) that brings together all the stakeholders. A boundary-object is an artefact around which actors form heterogeneous social worlds with different points of view – in those projects: urban managers, scientists, activists, neighbours, among others– manage to coordinate themselves.

In Rennes, a group of councillors decided to replicate a citizen-sensor-networks approach from Barcelona, Spain, which appeared in Carton and Ache's inventory. According to an urban actor in Rennes, there is a risk that the project, led by the local authority, could be turned against itself by some participants, driven by activist intentions. One consequence of this political risk is that the stakeholders present the measurement as a pedagogical tool and insist on the poor quality of the sensors, compared to expert devices: "It is not a citizen observatory, it is not citizen science" reminds a member of the project. This leitmotiv came from the confusion for the public on the purpose of this hybrid project and volunteer experience: talking about air quality and doing measurement.

The Effect of Sociotechnical Representations on the Choice of Measurement Tool

The quality of the sensors was not the only decision criteria, and the choice of the measurement tools was affected by several sociotechnical representations. We recount below the process of decision about tools selection.

During the project preparations in 2015, the ambition of the local authorities and partners was to build the complete infrastructure on their own: a mobile $N0_2$ sensor. It was originally not a $PM_{2.5}$ one, as finally decided, designed and made in the FabLab subsidised by the City and connected to a low rate frequency network, which is currently experimentally deployed in some areas of Rennes. The demands also called for a real-time visualization of the measurements and the data sent to an open platform. Several arguments were raised to justify the "sensors from Rennes". Firstly, a locally designed infrastructure, with an open licence, could guarantee independence from the digital space. Private actors, for example Internet service providers, digital companies – GAFA or start-ups, are joining a growing urban data market, in particular on air quality and environment monitoring. Secondly, building a tool with the participants was considered as a way to trigger curiosity about metrology. Finally, in June 2016, the Do It Yourself approach, with a FabLab collaboration, was abandoned by the stakeholders, because it was "technically infeasible". They discovered that a reliable and cheap NO_2 sensor, which fits a small and mobile box, does not exist. Furthermore, the councillors and the ADEME – the nation's expert agency and financial partner – had set the project's agenda to begin during autumn 2016, and it would have been too short in time to build a prototype. A participant, member of an open-technology activist association, who wanted to design a sensor, explained the sudden turnaround of the initial project:

No one had measured the entailed technical complexity. Emmanuel deconstructed each step of the project, and we ended up with a dozen steps. Each one would mobilize someone, between the building of the case, information dissemination, data formatting, storage on the IT servers, and visualization by the users… It is phenomenal!

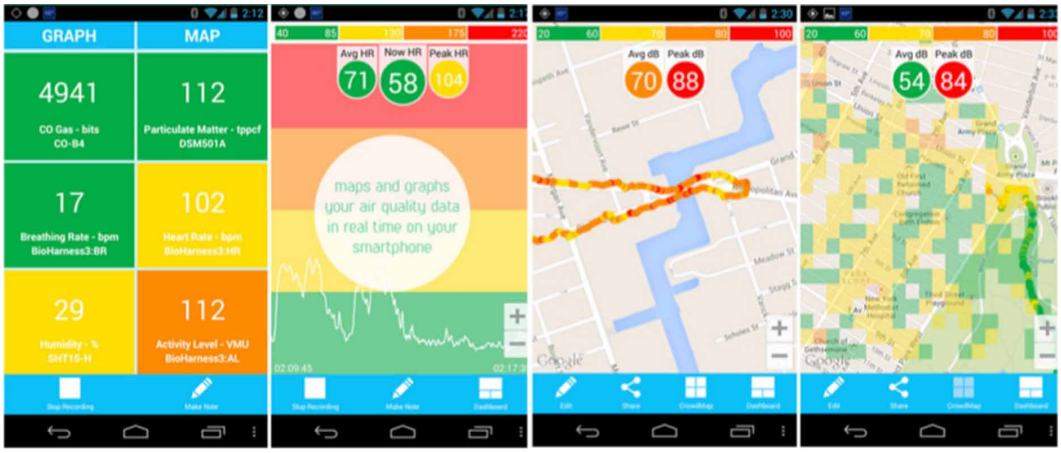
After a technological monitoring and a set of trials on several optical sensors that measured $PM_{2.5}$ levels, the stakeholders decided to buy a batch of Airbeam sensors, and as many smartphones. This sensor is made by a non-profit environmental health justice organization called HabitatMap, based in New York. A Bluetooth connection links both devices and the data transfer to AirCasting servers, supported by the Internet. A website offers visualization of all the data shared by the community of Airbeam users, and it gives the possibility to download the measurement files. All the technology is open-source and the user interface of the application, even if it is in English, is considered easy to use by the participants. In the scientific literature, a study compares some low-cost sensors, including the Airbeam (Jiao et al. 2016). However, an actor noted that there is a severe lack of information and specification on the operating conditions, uncertainly interval, and so on, on low-cost sensors.

By organizing citizen metrology, the urban public actors wanted to mobilise and sensitise the citizens, offering residents the opportunity to take measurements that give them the legitimacy to become an air quality ambassador. What we observed is that the stakeholders used the data from the sensor only to verify the concordance of the citizen measurement and regional expert's monitoring. The use of the data to produce local knowledge was not considered because of "the subjectivity and the non-scientific aspect of the data" according to an organizer.

METHODS

This study was based on an ethnography started at the beginning of the project in November 2016. In this article, we present the results of the first campaign, in 2016-2017. To analyze the participation process, we observed face-to-face workshops organized during the project. The participants were committed for a long period, for over eight months, and had to follow a two hour-long training sessions on air quality and on metrology with low-cost sensors. Other optional workshops, like mapping, viewing of films[1] with debate, and data-analysis workshops were organized. The measurement period

Figure 1. Screenshots of the AirCasting application



covered eleven weeks in January, February and March, because it is in the winter that particle matter peaks are observed.

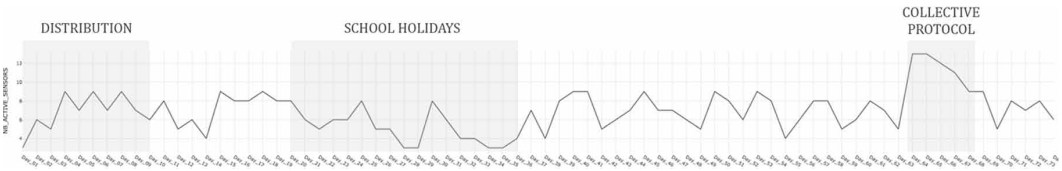
To study the participants' commitment and their perception of the project, we conducted nine semi-structured interviews with residents engaged in the first campaign of the Ambassad'air project. About twenty participants took part in the project for the 2016-2017 campaign – twenty were registered at the first meeting in October, but only sixteen continued with sensor readings in January. We contacted all of the participants for interviews with an e-mail and presented information during the workshop sessions. Five thematic categories of questions were posted to gauge their commitment to participating in the project, their perspective on environment issues, with their familiarity with the technology, their orientation toward citizen participation in urban public action, and their experience with $PM_{2.5}$ measurements with the sensors. We used the multi-thematic coding method to analyze the interviews (Ayache & Dumez 2011). The method consists in the use of a large number of heterogeneous themes that can be partially crossed. It aims to look at research materials according to several systems of similarity and difference to limit the risk of circular reasoning.

To complete the study of the participation, we have started to analyze the data set provided by the sensors used by the participants. The results of the measurement campaign of winter 2017 are an important dataset: around 700 .csv files have been shared on the AirCasting server. Every measurement, a record from the launch to the end, includes $PM_{2.5}$ values, temperature and humidity, with an interval of almost one second. One can also find sound level measurements, based on the smartphones' microphone. However, the conditions of the measurement process were usually not fully respected by the volunteers: they carried the smartphone in bags or pockets. Figure 1. presents the ratio of activated sensors for each day, based on this dataset. We included sixteen sensors carried by volunteers, and three others used by stakeholders (City employees, researchers from the EHESP school of Public Health, project partners). The delivery of the devices was conducted over a period of ten days from January 23rd. The peak of participation during the eleventh week corresponds to the implementation of a collective protocol.

Results on the Participants' Commitment

The group of residents that carried sensors were named "*les volontaires*" (the volunteers) by the facilitator. This word puts free will and their own choice to participate as preliminaries to any action. At every step of the project (e.g. workshops, design of measurement protocols, etc.), the facilitator reminded everyone that "it has to stay a voluntary action, and not too constraining". However, we

Figure 2. Number of activated sensors for each day



observed deep commitment. The first step was a small mediatisation of the call for volunteers: it was published in the municipal newspaper, and the information was sent to the mailing list of the *maison de quartier* of one of the targeted districts. Then, a public meeting was organized to present the main objectives of the project. Anyone from the two districts could volunteer by signing a commitment charter. With this small mediatisation, the public was also restrained to people who were already interested in local public action. Twenty inhabitants from the two districts responded. In this section of our article, we review different moments during the process (e.g. becoming a volunteer, staying a volunteer) and different situations (e.g. participation with or without measurement) to show the plurality of commitment in time and space.

Becoming a Volunteer: The First Step of Commitment

When we asked during the interviews about reasons to participate in the project at the beginning, four major points appeared, which we can analyze with Thévenot's framework on commitment: regime of familiarity, regime of regular planned action, and regime of public justification.

Firstly, several participants mention a civic action (regime of public justification). They considered participation in the project as an action that contributes to improving the environment. A participant explained that he was trying to follow and educate his children about "the environmental spirit", by which he meant:

[Interviewee]: Everything we could do ourselves, on our level, whether it is transportation, living in the city to own only one car for the whole family. We are not purists, but we're trying to do everyday things.
[Interviewer]: Assimilating eco-gestures?
[Interviewee]: Exactly. Embarking on this project interested me in the first instance. And this offer to measure pollution, I thought: that's really good.

Secondly, a few participants mentioned a contribution to the community (regime of public justification). One reason to commit was the particularities being a volunteer could bring to the group. For example, a resident who lived near the overhead railway, in service since 2002, and the ring road, justified her commitment by sharing an interesting observation specific to her location:

I hesitated before applying. I did it because I thought I was privileged, seeing what traffic can do to the air. Sometimes, there's a lot of traffic, which causes pollution. What about the underground railway? We try to clean the balconies, but they keep getting darker. There is black dust, which was not here before.

Thirdly, some participants mentioned personal use of the sensor (regime of regular planned action). With reflection about his or her own environment, volunteers attempted to verify and control personal exposure. The use of technologies is similar to quantified self-movement. The followers of this trend collect measurement about their daily exercise routine or daily nutrition to evaluate their performance and keep healthy. However, most volunteers, driven by this reason, also systematically

mentioned relatives or friends who had respiratory diseases, or that belong to a vulnerable population defined by the medical community (regime of familiarity). The metrology process gave them more information about daily risks.

Fourthly, most of the participants mentioned a personal interest in participating (regime of regular planned action). Curiosity about air pollution phenomena and socialisation within the group were common reasons described by volunteers.

Finally, we noted that not just volunteers used the sensors. Some of their relatives, colleagues and the stakeholders themselves took part indirectly in the metrology stage. A member of the urban service explained this phenomenon by attraction: "When you see them, you want to try". Nineteen sensors were in activity between January 23rd and April 6th. Sixteen were with volunteers.

Staying Volunteers: The Side-Bet and Technological Failures

Between October and April, seven workshops, meetings or trainings were organized, some of them on weekday evenings, others on Saturday afternoons. They took place either at the MCE in the city centre or in both districts. Volunteers appreciated the diversity in the schedule, which allowed them to incorporate the project among other obligations, professional and extra professional activities, family time, etc. In fact, volunteers said that the air-monitoring project was a low priority and had to be compatible with other activities.

In contrast with strong participation in the face-to-face workshops, we observed an important disengagement process during the metrology stage, due to technical difficulties. A participant relates his dismay:

In fact, smartphones are great, apps are great, utility items are great, but when they crash, it's not easy. I would have liked to measure more, but sometimes it crashed. I don't know why. […] I tried to reset, it lasted for twenty minutes, then twenty minutes again… After a while, it is annoying! Just that: when it works, it's great.

Memory failures, untimely updates, connection problems – in reaction, some participants put the sensors aside for a week, or more. Sometimes, they definitively abandoned the idea of taking measurements. Another volunteer, who had knowledge in computer science, decided to completely reprogram the sensor. He corrected software malfunctions and translated the application into French. In the end, his goal was to improve the sensor by adding a NO_2-sensor. We noticed that the disengagement process due to bugs and inabilities to manage them provoked a discrepancy with the feeling of obligation due to their commitment to produce some measurements and to contribute to the collective action. A participant said:

I have some insecurities because I didn't manage to commit, it's sad. I hope the others have contributed to the project.

However, bugs are not the only issue with technology that caused disengagement. For several volunteers, bringing contributions to the group collectively was not enough to inspire follow through with a daily commitment for eleven weeks. The sensors generated data files for each measurement, and the mobile application allowed the user to visualize only their own measurements one-by-one; they could not easily compare their own data with the one of other participants. A volunteer, for example, created a datasheet that compared the average value of her measurements with the value of the AASQA. She explained:

It allowed me to have a more concrete view of what I was measuring. Without it, I would take measurements, look at the results at night, but after two or three weeks, I would have given up. With the datasheet, it was a little more… I don't know… concrete.

Another volunteer recorded every measurement and observations about the context of that measurement in a notebook. Those additional inscription techniques are essential to the production of meaning, and are basic scientific tools (Latour 1985). Other volunteers also had a small science project (e.g. observation of the traffic impact on air quality, of the floor of the apartment on exposure) that they did not achieve, in particular because they did not have a way to do it. The lack of technology to access the data and transform it into information (Joliveau 2004), and to give sense to the action of measuring, had consequences on the long-term commitment process.

Being Involved in the Project: Different Participations, but Only One is Perceived by the Volunteers

The cross-analysis of interviews and observations of the workshops revealed that the meaning of participation was a focus for volunteers. However, the stakeholders did not have high expectations of the quality of the metrology and the specific knowledge or methods that could change in air quality monitoring. A participant, who stopped the measurements because the Bluetooth connection between smartphone and sensors was too instable, said:

[Interviewee]: It's too bad, because I really wanted to do something, but it ended up really annoying me. It saddens me, that's too bad. At least I learned a lot.
[Interviewer]: On the technique?
[Interviewee]: Yes. I took part in all the meetings, because I commit, I really do it.

Participation was also defined by other aspects of action. As we detailed above, the project had a pedagogical purpose. Air quality, environmental regulation, metrology, and technology were subjects that came up in daily discussions during the measuring period. All the interviewees agreed that "we are amongst convinced people", convinced by the necessity to act against air pollution, and they came here to learn more about the subject. A question was raised regularly: How to reach other audiences? Children, relatives, colleagues, and neighbours were identified by the volunteers as potential public. This position of relay, experienced by the participants, even if they did not see the purpose of their contribution to the project, is reflected in the project named "Ambassad'air", contraction of the French words "ambassadeur" (ambassador) and "air". Here is the response of one participant, when we asked him about this role:

[Interviewer]: Do you think you played the part of an ambassador for your relatives or colleagues?
[Interviewee]: I had experiences like that. It's not at work, because I work from home, but rather when I met people while taking measurements. It sparked the discussion. The hardest thing was to have enough time to explain all the aspects. […] On a large scale, I think it could be positive, because it would involve working people, and beyond.
[Interviewer]: Members of associations?
[Interviewee]: Yes, that's why I'm referring to working, active people, because we need people to spread the information to the general public.

On some occasions, the measurements illustrated a specific phenomenon and residents brought their observations to the expert on air quality. For example, on March 16th, for about ten hours, an intense increase was detected by the citizen-sensor-network. The AASQA did not notify the public about this peak, because the air pollution period must last at least 24 hours to be reported, and it is

based on a day-before broadcast. The model, crossing metrology and simulation, did not foresee the pollution event. However, two volunteers observed it:

We had two measurements with Patrick, which matched with March 16th. It was interesting. When I saw the data on my phone, because it was working at that point, I thought: That's weird, is it working well? That's when knowing the source and checking with the Airbreizh data is interesting. […] We haven't had feedback on that yet. It's interesting to witness something like that, not to wait for the sign: ATTENTION, POLLUTION PEAK.

With the sensors, they witnessed an event they could not perceive otherwise, and it gave them the possibility to ask the air quality monitoring expert for clarifications about alert procedures and air quality broadcasts. This relation between citizens and experts initiated a hybrid forum (Callon et al. 2001). However, the stakeholders of the project did not take the opportunities to propose a role of observers of pollution or local phenomena to the participants, due to the poor credibility of the sensor and the unverifiable context of measurement. We noticed that being involved in the project reflected different types of participation and commitment that were not always perceived by the participants: crowdsourcing, relay and citizen expertise.

Taking Measurements: A Search for Air Pollution Based on Perceptions and Representations

The sensors made a physical description of the visible environment: a more or less dense presence of particular matter larger than 2.5 µm in a small volume of air. The metrology can be considered as a strategy for use of an instrument and the translation of commitment into action. In the case of the ASQAA, the mission of air quality monitoring leads to developing a network of stations processing continual measurements. The strategies elaborated by volunteers are different because the device is mobile and the participant can turn it on or off if he or she wishes. To analyze the practices and the translation of commitment, we propose first to focus on the relation between what the participant perceives and what the sensor shows the participant. At some point, we observed that the resident questions his or her certainty of presence of air pollution. Verifying these perceptions and representations drives the metrology process. We present four ordinary situations that we observed:

Situation 1: *The participant sensed pollution through various visual or olfactory cues; he or she took a measurement, and recorded a high $PM_{2.5}$ level.* Air pollution is perceived via a number of sensitive cues: smelling chimney fire or muck spreading, seeing someone holding a lit-up cigarette, noticing bad visibility at the horizon, having some irritations or difficulties to breathe for the most sensitive people, etc. Those cues provoke the intention to measure.

[Interviewee]: At the moment, every time we're in the fields, it's horrible, with the spreading. I didn't measure anything, just noticed the phenomenon. It was this morning. Horrible! I need to measure it.
[Interviewer]: How did you notice it?
[Interviewee]: From the smell. Yes, the smell. Just by smelling, I didn't do anything special. I don't know how it affects me. At the same time, in the morning, it's so wet that I don't know if my measurements are reliable. I should check. Whereas in town, it's less important.

Metrology can confirm the participants' sensations. However, sometimes, the certainty of the presence of air pollution is refuted by the measurements.

Situation 2: *The participant perceived pollution; he or she took a measure, and recorded a low $PM_{2.5}$ level.* This situation is often observed with transportation: diesel cars, charged intersections, ring way proximity, traffic lights, parks and rides, etc. Transport is an important source of air pollution in urban environments, but as the ASQAA repeats: "Fine particles are not a marker of traffic, unlike NO_2". In other words, transport contributes to air pollution, but the difference between direct proximity and hundreds of meters is not significant when one measures $PM_{2.5}$. The discrepancy between measurement and representation troubled some volunteers. We observed the same phenomenon, with the comparison between outdoor $PM_{2.5}$ level and indoor $PM_{2.5}$ level. Most of the participants noticed that the level was higher outside than inside their home. Some of them concluded that their observation was in contradiction with the recommendations of opening the windows every day. Faced with this situation, which is certainly confusing, the stakeholders had to remind them of basic metrology principles: a sensor is made for one component, and air quality depends on multicomponent levels. Throughout the project, the idea of the necessity to find a multicomponent sensor increased in participants' discourses.

Situation 3: *The participant recorded a high $PM_{2.5}$ level, and he or she observed the environment to find a cause.* In this case, knowing that the level was high was not enough. The cause of pollution had to be identified. At times, the explanation can be found: canyon effect, temperature inversion, visible sources, cigarettes, etc. Other times, the representation of sources and conducive weather conditions with high $PM_{2.5}$ level did not match with the environment of measurements. A participant said, for example, that she was surprised that the sensor showed a higher $PM_{2.5}$ level when she was running along the river than in another place on a path. In this case, a hypothesis came out after a collective discussion, that the optical sensor overvalued $PM_{2.5}$ levels when the humidity was high.

Situation 4: *The participant did not perceive pollution, so he or she did not take a measurement.* This situation resulted from the idea, shared by several participants, that the metrology entailed a search for air pollution that could assist in identifying sources. An example of this situation is narrated by a volunteer:

I took a few roaming measurements, given that I have a dog, I need to take her out often. Every time we went out, I measured. I did not do it when it was raining, because it was useless, the fine particles rates were very low.

We can see with these four situations of interactions with the sensor that there is a difference in metrology strategies between the air quality monitoring, as the expertise proceeded, and the citizen metrology observed, based in particular on perceptions and representations. However, we could not characterize citizen metrology in this program based on isolated situations alone (e.g. application of the regime of familiarity in Thévenot's typologies), because protocols were proposed, and sometimes followed too (regime of regular planned action).

Taking Measurements: Routines and Protocols Followed by the Participants

During a meeting presenting the sensor device, advice on metrology was given, which was necessary for later analysis of the aggregated data: "take long and repeated measurements", "take fixed measurements rather than mobile ones," and "take measurements in teams". Those pieces of advice corresponded to the basic conventions used in air quality monitoring. During an interview carried out at the beginning of the first campaign, the project leader explained why no specific protocol other than the advice had been given: first, too strict a protocol could restrain participation. This would have been perceived as a top-down and not a bottom-up project, and the protocol should be decided with participants. The last argument was that participants get a lot of ideas, and the diversion (De Certeau

1990) of the sensors from outdoor air quality measurement (e.g. indoor measurement, cigarette or barbecue effects) could be interesting to include in the project.

We observed that along the set of meetings and workshops, the advice to take long, fixed and regular measurements – was repeated often to frame (Goffman 1974a) the metrology practice. Categorizations were also determined between participants and stakeholders to facilitate the re-use of data: fixed or mobile, indoors or outdoors, on foot, on bicycle, on car, the districts, the time of the day. Those descriptors had to be added to the file name when the measurement was saved, because the app did not have the option to characterize the file. We noticed that every participant encoded the metadata differently, and it made the design of an automatized process for classification complicated.

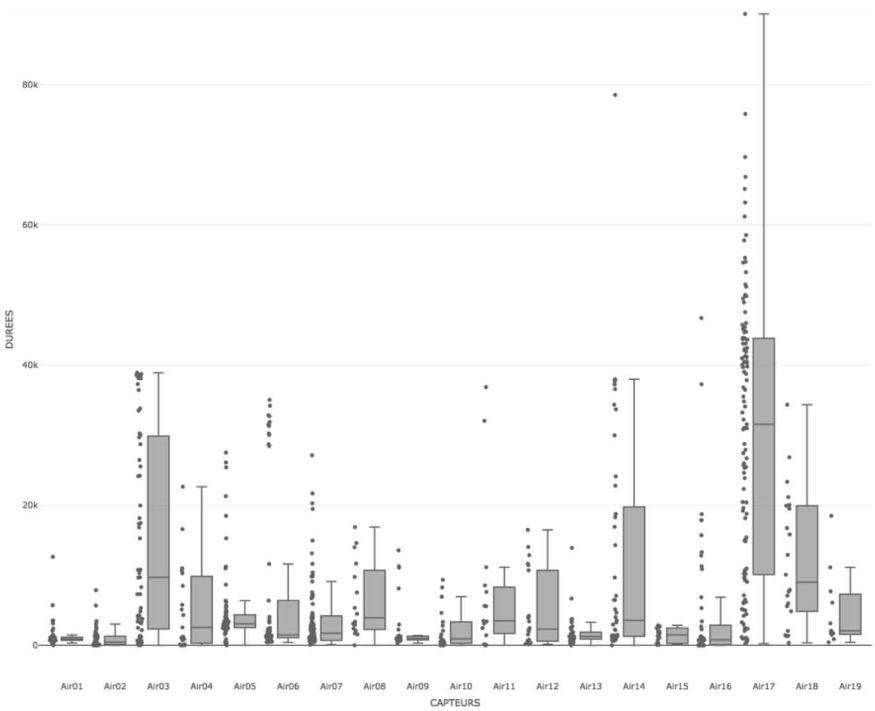
An analysis of the measurement duration with the sensor distribution showed that the participants also had different practices, as we can see in Figure 3.

Throughout the study, we noticed that most of the volunteers declared having the intention to observe a specific situation they considered a potential issue, or they believed to have an influence on air quality. These intentions included the desires to evaluate the impact of local traffic on air quality; to control the incinerator emission; to prove the potential of $PM_{2.5}$ captures of lobed-leaved trees based on a lecture of a scientific article (Janhäll 2015); to evaluate the exposure of urban cyclists; and to verify the hypothesis that the $PM_{2.5}$-level varies depending on the altitude, such as between two floors in a tower, and so on.

To run their experiments, some participants created individual protocols, and "programs" that they attempted to follow (regime of regular planned action). Here is one example:

If it had worked, I would have taken measurements for a week every morning and night on my balcony. But I had trouble making myself available to turn it on every day at the same time, because there's always something going on. […] I had planned to do a week at such hours to compare the different

Figure 3. Distribution of measurement durations (in seconds) for the fleet of sensors



days of the week, to compare Wednesdays to other days, Fridays and Mondays, which are not always the same when it comes to traffic.

Another participant had the intention to follow the third piece of advice: "take measurements in teams", she said:

With my neighbour, we're going to try to measure the effect of direct proximity with the incineration plant and the boulevard. We live in an L-shaped building. She is taking care of the boulevard, and the plant. I have the rue d'Alsace. We decided to take the measurements together.

At the end of the measurement stage, during a workshop about data analysis and sharing experiences – in majority, isolated measurements – the group decided to go on an additional week to follow a collective protocol (regime of public justification). The instruction was to turn on the sensor between 7pm and 10pm at least and to measure the outdoor air quality. This collective action appeared by a bottom-up approach and came at the end of the metrology stage. The mobilization increased, as we can see in Figure 2.

In addition to those intentions of measurements, and the individual or collective trials, carried out or not, we noticed that turning on the sensor became a routine for the participants (regime of familiarity). This is transposed in the interviews with sentences like: "every time I go out, I take the sensor". The metrology practice is inserted into the ordinary day, mainly on weekdays, during one or two regular activities: home-to-work commutes, sport sessions, daily walks, etc. Fixed measurements were usually made during night-time and go on until the next morning. In Figure 3, one can identify them when the duration is between 30k and 40k seconds – approximatively 8 and 11 hours.

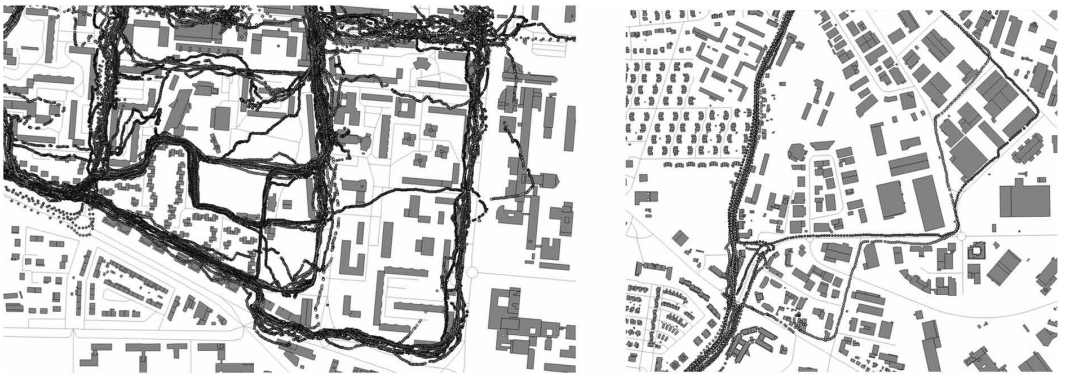
The routine measurement produces repeated measurements and patterns, like the map in Figure 4.

DISCUSSION AND CONCLUSION

The hybridisation between science and politics has been a question raised by sociologists since the early 20th century with the text *Politics as Vocation* by Weber (1917). Nowadays, we observe a new kind of hybridisation with the emergence of initiatives promoted and organized by municipalities, which take the forms and tools of citizen science without any scientific or research approach to act on public issues. The Ambassad'air citizen metrology project in Rennes (France) succeeded in mobilizing stakeholders and inhabitants on air quality issues using AirCasting devices. It can be considered as an urban public action instrument (Lascoumes & Le Galès 2005), whose principal aim is to inform and to raise awareness about air pollution within local publics. Political risks of counter-expertise controversies and low-cost sensors with uncertain reliability led the project to a pedagogical purpose and to minimize the importance of further scientific uses of the data.

The results of the case study show that the volunteers have plural commitments, and they were often mismatched with the city's expectations of the participants' contributions – the air quality ambassador position. Beyond their personal commitments categorised as the regime of familiarity and regime of regular planned action (Thévenot 2011), some of the interviewed participants wondered at the end of the project what the purpose of taking measurements was, the data was not perceived as having produced local, collective knowledge. Beyond the dysfunction of the devices, we also noticed that the impossibility of processing data easily triggered disengagement in several participants: the technology did not give them a way to follow the individual intentions and protocols. With the AirCasting tools, the participants could not proceed with the logical operation of data analysis to study air pollution phenomena. Discussions about hypotheses, methods or results during the workshops rapidly turned to limitations of the sensor devices. However, some participants had high scientific education (e.g. a researcher in ecology science, an engineer) and during the interviews, we noted that

Figure 4. Examples of routines – traces produced by daily walks (left), by daily cycling paths (right)



the interviewees were aware of the basic principles of environment science (e.g. to control the sensing condition). The design of programs with low-cost sensors should be done with careful reflection on the collaborative analysis process and not only on data visualisation.

However, citizen metrology as citizen participation (Blondiaux & Sintomer 2002) was a success according to participants and stakeholders, because it generated a public arena: discussions on health environment, on urban strategy are appearing even if the project did not integrate a decision-making process related to urban planning. In the long term, the question is how this hybrid project and the useless data – from the collective point of view – can have an influence or effects on the public debate and how the process is perceived by the participants, by the stakeholders and by outsiders of the project. The scientific literature proposes several models, such as the boundary-object (Star & Griesemer 1989) and the micro-world (*micro-monde*) (Chateauraynaud & Debaz 2017). A micro-world is characterised by a large autonomy from other communities' habits: 1) with its hybrid shape the project Ambassad'air is different from other typical citizen science projects, because it did not have the ambition to be recognised by the scientific community; 2) with its objective the project Ambassad'air is different from other typical citizen participation in urban public action, because it did not act directly on the decision-making process of urban planning. The research data used came from the first Ambassad'air campaign only. The project has been renewed for two more campaigns, which will allow the authors to conduct additional observations to study how stakeholders maintain the hybrid characteristics.

Lastly, the practice of measurement made by citizens with a fleet of sensors, and the question of the uses of this data, raise the need to think about methods and models of metrology based on a fleet of uncertain and intermittently functioning sensors. In fact, with this study on citizen metrology and commitments, we observed that the use of sensors is based on strategies that were influenced by perceptions of the urban environment, representations of air pollution, and ordinary routines. To be able to study the practices of citizens as sensors (Goodchild 2007), we suggest broadening the focus of Human Computer Interactions, with the Human Environment Interactions, and Social Interactions (Goffman 1974b).

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ENDNOTE

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