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Method article

Large-scale citizen science protocol provides high-resolution nitrogen dioxide values while enhancing community knowledge and collective action

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ABSTRACT

We present an already tested protocol from a large-scale air quality citizen science campaign (xAire, 725 measurements, see Ref. [1]). A broad partnership with 1,650 people from communities including 18 primary schools in Barcelona (Spain) provided the capacity to obtain unprecedented high-resolution NO_2 levels. Communities followed the protocol to select measurement points and obtain NO_2 levels from outdoor locations n=671, playgrounds n=31, and inside school buildings (primarily classrooms) n=23. Data was calibrated and annualized with concentration levels from the cityś automatic air quality monitoring reference stations [2].

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Specifications table

Subject Area:	Environmental Science
More specific subject area:	*Air Quality*
Method name:	Citizen Science protocol for high-resolution nitrogen dioxide values in urban contexts
Protocol name:	xAire - *Collective air quality measurement*
Reagents/tools:	*xAire used Palmes' diffusion tubes (passive samplers) to measure NO_2. Palmes sampler consists of an acrylic tube 7.1 cm long and 1.1 cm internal diameter, two stainless steel grids and two caps. A chemical reagent is used to absorb the pollutant to be measured directly from the air. The absorbent used is 20% triethanolamine (TEA) deionized water.*
Experimental design:	*Large-scale campaign to monitor NO_2 concentration levels in urban contexts and by means of citizen science practices.*
Trial registration:	*NA*
Ethics:	*NA*
Value of the Protocol:	• *The protocol for large-scale citizen science campaign contributes to the effort to raise awareness about community exposure and lower air pollution in urban areas.* • *It can be valuable in the interplay between advances in exposure assessment and policy.* • *Citizen science campaigns provide cost-effective and unprecedented high-resolution air pollution levels on a scale that goes beyond the capacity of routine monitoring stations.* *Environmental Science*

*Method details

As a partner of the xAire project, the Barcelona Education Consortia (public schools' municipal network, Consorci d'Educació de Barcelona, CEB) engaged 18 primary public schools evenly distributed among the 10 districts of the city. Provided with a methodology protocol and an initial training session, schools organised mixed groups of 4-5 people with parents and children and autonomously placed up to 800 Palmes passive diffusion NO_2 samplers in a coordinated manner, following a standardized protocol, resulting in 725 valid data points (671 outdoor, 31 outdoor playground, and 23 indoor school, between February 16th and March 15th, 2018, four weeks). Each of the schools interpreted the data and provided a set of conclusions and requests for action during the Barcelona Science Congress, where young students presented and attended, with the presence of the Barcelona Mayor. The schools also promoted the organization an event at the Town Hall where representatives for each school delivered results and calls for action to the Deputy Mayor of Ecology, Urbanism and Mobility, and the Commissioner of Ecology. Data is available [2]. Previously in Barcelona, large simultaneous sampling has only been conducted by professional scientists. This project represents the first collaborative effort to collect and analyze data on a large scale to address the challenge of air pollution in the city.

Participants were informed about the protocol details, and these were publicly discussed during an initial training session for teachers and families that also served to improve some aspects of the scientific protocol. Each class group was asked to plot the 40 NO_2 passive samplers on a map during class hours, at home (with families), and eventually during a walk in their respective neighborhoods. They chose their preferred locations through discussions with teachers and families according to the following criteria: 1) each school had to include one location at the main entrance of the school, one in the playground and one indoors 2) the rest of the samplers were to be deployed outdoors aiming to achieve background (at least 10% of the samplers 300 m away from motorized roads) and traffic-orientated locations, avoiding specific spots such as bus stations and intersections, and placing samplers at least 100 m distance apart from each other. One week before starting the collective sampler placement, and to avoid overlaps or anticipate problems, each school delivered a map to the xAire coordination team indicating where their samplers would be located. An overlap in sampling locations in two schools and an overly dense samplers' distribution in one school were detected during this review. This resulted in the redistribution of half a dozen sampler locations.

School representatives came to pick up their 40 samplers during a meeting on the day prior to placement. This meeting served to finalize logistical details and resolve remaining questions. The samplers were installed simultaneously on the following day, and they were removed simultaneously 4 weeks later (the optimal timeframe to maximize Palmes samplers' precision). Groups spent up to 2 hours to complete their placement routes. As described in the protocol, each group brought a small ladder to place the samplers into a bracket fastened to the chosen location at approximately 2.20 m high. Each sampler was identified with a four-digit numeric label. The participants then completed a paper-based table with the address and the GPS coordinates (using their own mobile phones) together with the reference code of each sampler. Each sampler was also classified depending on its location: indoor (inside the school), playground (outdoor), outdoor urban traffic and outdoor urban background. The same operation was repeated during sampler removal. Installation and removal forms were completed using a double verification procedure. Using mobile phones, participants took a picture of each sampler (clearly identified) in its location. Each school uploaded all information into an online form jointly with scanned versions of the paper records to double check how accurate were participants informing about all different aspects that were needed to be reported (see Ref. [1]).

As a control measure, blank samplers were used across the study to detect any contamination during the shipping. The results of the blanks were below the detection limit of the sampler. The exact location of the sites was verified by different means: GPS readings on site using phones or tablets or using desktop tools like Google Maps. The scientific team reviewed all site locations to ensure all locations were reported accurately, which was the case for more than 90% of the samplers. Data calibration was performed by professional scientists to ensure accuracy and precision of the measurements in relation the under or over estimation on NO_2 concentrations and to provide further adjustments to deliver annualized NO_2 concentrations. To accomplish this, triplicate samplers were placed close to reference automatic stations. See Ref. [1] for further details on these aspects.

The xAire project distributed a total of 800 passive samplers to different school groups, and this joint effort resulted in a total of 725 NO_2 valid concentration level points (91% of the total samplers). 75 samplers were invalid for several reasons (e.g., water or insects inside the tube, excess sunlight exposure, being knocked down by a ball in a playground area…). In a few cases, the samplersdisappeared as they did not have any protection when placed in the outdoor public spaces.

Instructions for participants

This protocol provides instructions that each community or group (e.g., 7-12 year-old children, families and teachers) received. Each group worked separately but shares the maps and the NO_2 concentration levels. Each group met before and after the simultaneous, collective air quality measurement. The process included a coordination team for monitoring and technical assistance throughout the project. Each community had a designated representative that connected directly to the coordination team.

Samplers' location

Work with the local group or organize an activity that allows you to consider where to place the samplers to measure the monthly concentration of NO_2.

Details to consider:

1. USE a (digital or non-digital) map of your neighborhood. Measurement points should not be widely shared until the project is over to prevent vandalism and other incidents that reduce the reliability of the measurements as a whole. Also keep in mind that you will have to distribute to the participating groups the map in paper format with the previously agreed points during the sampler placing phase.
2. DISTRIBUTE the 40 spots on the map based on the following criteria:

   - Chose a spot at the school entrance and from there spread the dots in one or more directions to cover your neighborhood. This will help the creation of specific routes during the deployment.

- Measurement spots should be places that interest you because you want to know the NO_2 levels in the public spaces where you spend time. They can be paths to go to school, streets to go to the most central part of your neighborhood or city, streets to go to work, streets that people use to go for a walk or sit, spaces where children go to play…
- The spots must include two types: traffic and urban background. The traffic spots are next to streets with motorized vehicles. In this case the samplers will be located at streetlights and traffic signs that are usually located less than 1 meter from the road. Urban background spots are those located more than 300 m away from roads carrying motorized vehicles (parks, squares, green areas or pedestrian streets). Try to balance the two choices and choose a minimum of 10% urban background locations.
- Each sampler should be at least 100 m away from any other sampler.
- The spots must be in a safe location that also allows free air circulation and more than 10 meters away from air vents, fans, taxi or bus stops or intersections and traffic lights.

3. REVIEW, in situ, each of the locations you have chosen. You can organize a walk around the neighborhood with the group of participants. This way you will be sure that they are ideal places to take NO_2 measurements before ‘placement. Note that you will need to place the samplers at a height of 2.20- 2.50 m on a streetlight, traffic signal or similar.
4. ORGANIZE the logistics for the samplers' deployment (it should be during the same time period and on the same day for all participating groups). Create teams of at least 5-6 people. You will need to distribute the different tasks to make samplers' placement more efficient (see below).
5. SEND to the coordination team either the map on a digital platform (shared in private) or a scan (with a list of points with a simple description) of the map on paper in advance.

A representative for each community should come to the map sharing session. There will be a joint review with all communities engaged to avoid overlaps. There will also be time for questions and collective discussion.

For schools: KEEP A MAXIMUM OF 5 SAMPLERS OF THE 40: ONE IN FRONT OF THE SCHOOL, UP TO A MAXIMUM OF THREE FOR THE PLAYGROUNDS AND ONE FOR A CLASSROOM OR COMMON AREA.

Sampler deployment

Every community group will collect 40 samplers in airtight bags on the day before the collective air quality measurement. It is important that you install the samplers within the same timeframe. You can organize yourself into small groups of 5-6 people to share areas of your neighborhood. You will have one person from the organization per school and district that will provide you technical support if necessary and with the aim to respond quickly to any incident.

Within the groups, we recommend that you distribute the necessary tasks:

- Designate a coordinator in each small group who can report problems and connect with the coordination team
- Bring the map and plan the optimal route.
- Attach the label to the sampler halfway up (you can do this before leaving).
- Attach the bracket holder that attaches the sampler to the selected spot with a plastic tie and cut the ends.
- Hang the sampler (remember to bring a chair or small ladder) at 2.20-2.50 m high. Use a rope with weight to make the operation smoother.
- Fill in the form (remember to bring the material and pencil) including a duplicate of the label and its number.
- Mark the exact place on the map.
- Write down the GPS coordinates (remember to bring a mobile phone with an application that provides this information) and the address (street and nearest street number).
- Take a picture and collect the GPS coordinates.

Finally, be very meticulous by following these steps:

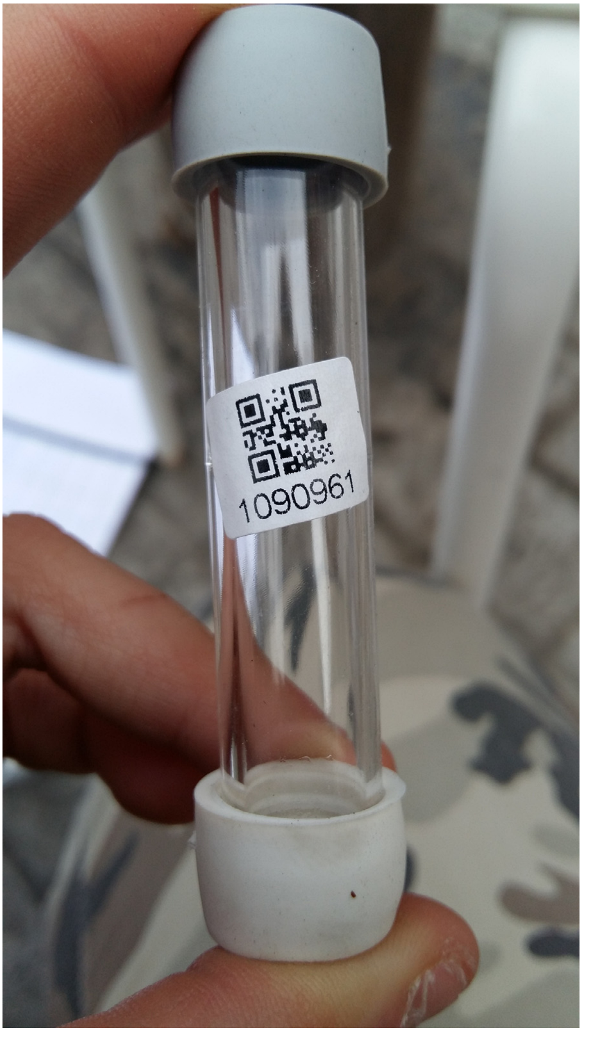

Fig. 1. Palmes passive sampler with its code.

1. INSTALL the sampler vertically into the holder with the white lid facing down. Use a flange to attach to a streetlight, traffic sign or similar. Put a QR code label and a number on each sampler.
2. PLACE the sampler in the chosen location. It must be a safe location that allows free air circulation (without any obstruction) and more than 10 meters away from air vents, fans, taxi or bus stops or intersections. Place the sampler at a height of 2.20-2.50 m, high enough to prevent theft and vandalism. If it is a busy street, make sure the sampler is oriented to the lane where cars pas.
3. REMOVE and store the white lid (bottom) of the sampler, leaving the lower end of the sampler open and on display for 4 weeks.
4. DOCUMENT the location of each sampler with the following steps:

   a Complete the sampling sheet with the exact time, reference number of the sampler and the duplicate label, if it is close to a busy street (traffic) or more than 300 meters from a road with cars (urban background) and any information of interest.

b Mark the exact location on a paper map and pick up the coordinates given by a GPS (there are multiple free mobile apps that allow this) and the address of the nearest building.
c Take a photograph of the sampler installed with the mobile phone where its geolocation is also recorded.

5. SAVE the sampling sheet, the white cover of the sampler and the map in the airtight bag.
6. INFORM the coordination team by email and mobile phone about how the experience went. Attach photographs of each of the points, a photograph for each spot and the map with the marks of the observation points.
7. Periodically check the samplers' during the following four weeks and report any incidents.

On the same day of the community sampling, organizers should also place samplers near official monitor stations to obtain comparable values and enhance precision and accuracy [1]. For this reason, during the xAire measurement campaign, samplers were placed in triplicate at 8 automatic reference official air quality monitoring stations in the project area. These included different types of stations classified according to EU Directive (Directive200850CE): urban traffic (3) and urban background (5). This step allows for calculating the precision and accuracy (correcting bias).

Samplers' collection

Four weeks later, activate similar groups collect the samplers. Bring the sheets and the map used when originally placing the sampler tubes. Validate and thoroughly review all information. It is important that to collect the samplers within a pre-stablished timeframe on the same with the participating groups.

1. REMOVE the sampler from its holder and cover it with one of the saved white lids. If you are missing a cap, you can cover it with tape (if you are aware you lack caps before collection, notify the coordinators to receive new caps). If you find spiders or any insects, leave them inside and document this on the sampling sheet.
2. MAKE SURE the sampler is well covered and the sampler number matches what you wrote on the placement field sheet.
3. DOCUMENT by completing the sampling sheet with the time of collection and any incident (e.g., insects or water inside being damaged or missing). Take another geolocated photo of the point with the sampler in hand and that the reference number can be read.
4. SAVE the sampling sheet, tightly covered sampler and the map in the airtight bag. A designated person will collect the bag and take it to the coordination so that samplers can be sent to the laboratory the same day. Make a digital copy of everything and email it to the coordination team.

MAKE SURE YOU COLLECT ALL SAMPLERS. THEY CANNOT BE SENT TO THE LAB AFTER THE DESIGNATED COLLECTION TIME.

Data obtained

Data analysis from the laboratory typically takes 1 month and requires calibration (see [1] and [2]). Teams receive back an excel sheet with the number of each sensor. Collectively arrange the data on a map (provided) or you can directly use platforms such as https://mappingforchange.org.uk (you need to ask permission to use this). You will be able to see the pollution levels and whether each of the places exceeds the level of 40 $\mu g/m^3$ established by European Union Directive 2008/50 / EC and RD 102/2011 and which constitutes the 2017 WHO reference level. Once the data has been reviewed by the participating groups, you can organize events and communication to share the results and propose actions data. The data will be left open under creative commons license. Each community is invited to interpret the data and deliver recommendations to improve air quality in their cities.

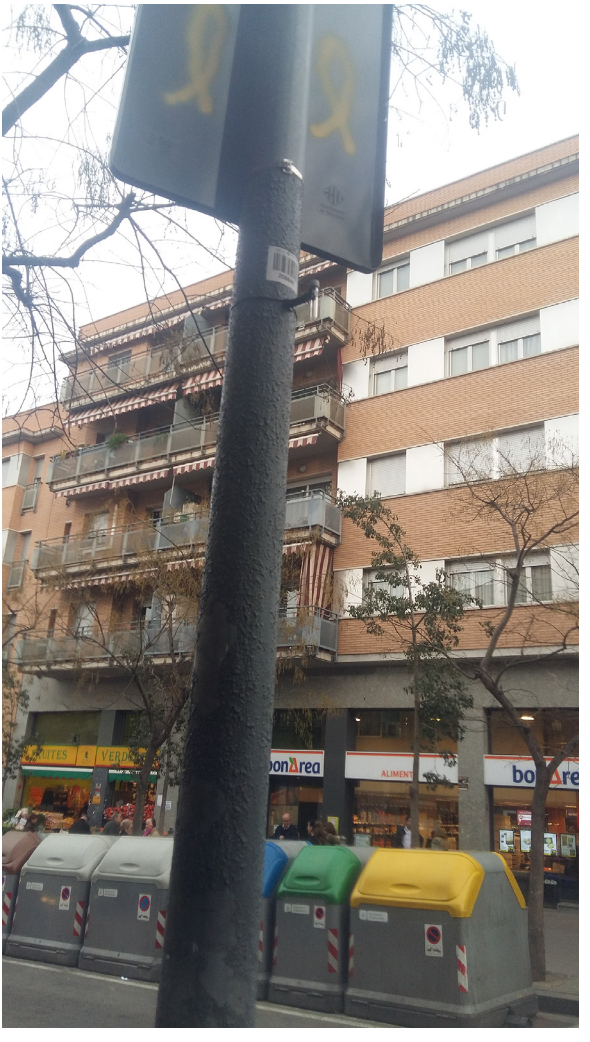

Fig. 2. Palmes passive sampler attached to a traffic sign post.

Instructions for organisers

You will need to supply samplers to participants. An initial training session and create a coordination team to enhance communication with all communities engaged is essential. Having an event the day before the large-scale deployment is also advisable. We suggest organizing a discussion of collective actions and joint events to share and communicate the results at the city level. If you collect a large number of samplers, you can organize a public event with your municipality to discuss air quality in your city [1]. The map with results is a particularly powerful communication tool because it is highly visual and let people find and compare locations that are part of their daily lives (Figs. 1 and 2)

Supplementary Material: Example of a form where samplers' deployments is documented. It is also possible to create a table or a digital form with these fields.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.mex.2021.101475.

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