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Urban air quality citizen science

Phase 3: Findings of the pilot studies

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Summary

This report provides a summary of the pilot studies conducted in Glasgow, Edinburgh and Prestonpans to test the viability of citizen science air quality monitoring studies within the constraints of existing and available technologies.

The pilot studies draw on the experiences with the testing and evaluation of low-cost air quality monitoring devices described in the *Scoping report reviewing and evaluating methods for undertaking an air quality Citizen Science programme* and by Semple et al. (2012), while the overall study design is based on the framework discussed in Steinle et al. (2013). Furthermore, the pilot studies are based on the detailed elaboration of pilot studies summarised in the report *Urban air quality citizen science - suggested programme of research projects*.

Two different pilot study approaches have been selected to test both a stationary air quality monitoring setup in the context of a secondary school, including the viability of using devices and monitoring methods in regular teaching activities, and using a mobile setup (with small backpacks including the air quality monitor as well as a GPS for geo-referencing). For the latter, the focus was on cyclists and volunteers were approached through existing contacts within the bike charity SPOKES (www.spokes.org.uk) and – through Transport Scotland – the Glasgow Bike Station.

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1 Introduction

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The main effort was not on providing air quality measurements, but on testing the approaches, methods, devices and engagement with citizen scientists. Thus, the focus of this deliverable is on the evaluation of these aspects.

It should be highlighted that the particle counters deployed in this pilot study are only able to provide indicative particle mass concentrations only, based on a function derived in a co-location study with a TEOM-FDMS instrument at the Edinburgh St. Leonards fixed monitoring site. This is vital to allow for a direct comparison with limit values or data from fixed monitoring sites, but does not provide mass concentration data that has been generated subject to the same quality criteria from reference monitoring technologies. However, the indicative mass concentrations derived are robust in their variability and provide a good indication of concentration changes based on research conducted by both the University of Aberdeen and CEH.

A direct comparison with Scottish target value for $PM_{2.5}$ (12 µg/m³) or the guideline value of the World Health Organisation (WHO, 10 µg/m³), both annual mean values, would require full 24 hour monitoring over a longer (ideally for the full year) period.

2 Description of pilot study setup

2.1 Overview

Based on the outcomes of the consultations with the advisory group and the steering group in phases 1 and 2, the pilot study in phase 3 was designed to be held in two areas. A first focus was on schools, in particular investigating how cars idling outside schools at drop-off and pick-up times, and/or playgrounds close to busy roads may affect local air quality and exposure. Initial consultation with the

[1] Available at: http://www.environment.scotland.gov.uk/about-us/lifeplus-project/lifeplus-project-news-and-updates

teachers and education specialists who form the Scotland Counts Schools Working Group and existing contacts established through previous Scotland Counts schools engagement enabled identification of a number of potential schools. The school finally identified in this process was Preston Lodge High School in Prestonpans, East Lothian, which provides level 3, and senior phase education for around 1,000 learners from the communities of Prestonpans, Longniddry and Port Seton. A second pilot study was designed to use volunteer cyclists to track pollution as they cycle round their city. First contact was made through existing contacts of the study team at SPOKES. An additional contact was established through a recent engagement with Transport Scotland, who had been working with the Glasgow Bike Station during a staff day out using a monitoring pack.

The pilot studies focussed on the issues around recruiting participants to the projects and keeping them involved; and on collecting and processing the data (including how it may be integrated into SEWeb). The sensors/technology used have already been trialled by CEH and the University of Aberdeen both for outdoor mobile monitoring (Fig. 1. left) and indoor air pollution assessment (around Second Hand Smoke, SHS). For the stationary deployment outdoors a rain cover has been tested during a co-location study at the Edinburgh St. Leonards fixed monitoring site, which was made available to the school (Fig. 1. right). The rain cover is essential as the Dylos 1700 is not originally designed for outdoor use. While the cover may affect air flow, the active ventilation of the device does not seem to be affected by the cover when tested.

Fig. 1. Illustration of the monitoring pack for mobile measurements (left) and the rain cover and tripod for stationary outdoor deployment (right)

2.2 Stationary Monitoring - Preston Lodge High School, Prestonpans

Following initial engagement by phone, a first meeting was set up at Preston Lodge to discuss options for the deployment of a Dylos 1700 particle counter and explain the technology and applicability. Two chemistry teachers attended and were enthusiastic about the potential for the integration of the pilot within classes. Three options for involvement in the pilot were proposed ranging from full scale engagement from pupils, including the production of a video diary, to simple monitoring with one teacher and a small group of pupils. Subsequent contact with the teachers to determine their preferred option proved difficult to establish, but eventually the school responded proposing that a geography teacher supervise the simpler option discussed at the initial meeting. The monitor, tripod and rain cover were supplied to the school on the 6th of February 2014 and full training was provided. Due to school holidays, monitoring activities were not planned to commence until 17th of February.

The device was used for both stationary monitoring at the school grounds and a short motorbike trip inside Edinburgh city centre by one of the teachers to explore different use options. Monitoring activities took place and were documented with notes on location, activity and meteorological conditions (see Table 1). The equipment was picked up at the school grounds on 25th of March.

Data evaluation commenced immediately after pick-up and feedback received from the teacher using the device was that he had been unable to directly access and retrieve data from the Dylos monitor with a Windows XP based laptop. Data retrieval using both the legacy Dylos software, and alternative terminal software was only able to download logs for two dates, 27th and 28th of February, without any further data having been logged. Testing the device resulted in normal logging operations, leaving no current explanation for the data loss or failure of the instrument to log data for the remaining days. Analysing the time stamps, it appears that the only data stored by the device was from the 27th to the following morning. This dataset has been analysed and is displayed in Fig. 2.

Table 1. Preston Lodge High School monitoring activities

Date	Location	Comments
20/2/2014	Geography classroom	Running during period 5 & 6 (1:45-3:45)
27/2/2014	Pupil house	Left to run overnight*
28/2/2014	Motorbike transit from Castle Terrace through Edinburgh Old Town and transit from Princes Street to Newbridge along Corstorphine Rd	Measured in conjunction with a video of the route taken. Overcast, slight wind from west, showers, approximately 5 degrees C
4/3/2014	Recycling bin area at the front of the school	Overcast, sited in shelter from wind, approx. 5 degrees C, running from 8:00 – 9:30
5/3/2014	Recycling bin area at the front of the school	Overcast, sited in shelter from wind, approx. 3 degrees C, running from 8:00 – 9:30
11/3/2014	Rear car park	Positioned on roof of a car, clear day, slight breeze, 12 degrees C, running from 15:00 – 16:00
12/3/2014	Rear car park	Positioned on roof of a car, clear day, slight breeze, 10 degrees C, running from 15:00 – 16:00

* it was unclear from the feedback received if the monitor was set up indoors or outdoors

The Dylos 1700, as all light-scattering instrument, records particle numbers and thus does not directly measure particle mass, which is how air quality limit values or reference measurements are expressed. To compare the recorded values directly to air quality limit values and other measurements, e.g. from the Automatic Urban Rural Network (AURN), we applied a linear function based on a co-location study at Edinburgh St. Leonards to derive indicative $PM_{2.5}$ mass concentrations in µg/m³ based on the recorded "small" particles (i.e. between 0.5 and 2.5 µm aerodynamic diameter). The graphs in Fig. 2 display both the indicative $PM_{2.5}$ mass concentrations and the raw data (particle number counts) for the small and large size bin respectively for information. In most cases, these values follow similar patterns, but the ratio between the small and the larger size bin can at times provide additional insight about possible sources of peaks etc., where the 0.5-2.5 µm fraction likely to stem from long-range transport or direct combustion emissions (e.g. from a car/truck/bus nearby), while the larger fraction typically being more affected by windblown dust, sea salt etc. On the 27th, the afternoon levels started out relatively low around 7.5 µg/m³ and then increase to about 11 µg/m³ after 3 pm. The measurements were started again at 20:21 on the same day and show another peak around 9 p.m. to then gradually drop off during the night (this is typically seen in indoor environments when people settle for the night, due to particles settling over time with numbers going down due to less movement and activities). On the 28th, starting from 6 a.m., levels remain relatively low again at about 6 µg/m³ to then sharply increase to a maximum of more than 140 µg/m³ around 8:10, which is a substantial peak and shows in both the small and larger fraction of the particle number count. A preliminary interpretation of this peak suggests one or more sources of $PM_{2.5}$ in the direct vicinity of the monitor for a short period of time. Potential explanations for this peak will be discussed with the school at a face-to-face debrief meeting to be scheduled in the near future. It has to be noted, however, that due to the aforementioned problems with data loss in this pilot study, the main lessons learned from this pilot study would be on the engagement process, while the actual measurement results are of limited value. The measurement results are displayed in Fig. 2 (overall measurements on the 27th and 28th of February, top left; zoom-in to times with high variability top right and bottom panels).

A direct relationship of this peak concentration to health effects is difficult, as the guideline value of the World Health Organisation of 10 µg/m³ applies to an annual mean concentration and at this time, no short-term limit values have been discussed or set for PM2.5. However, a regular occurrence of such short term peaks would without doubt affect the 24 hour and annual mean value and if at a location where students and staff are likely to be exposed on a daily basis, would suggest a potential health risk.

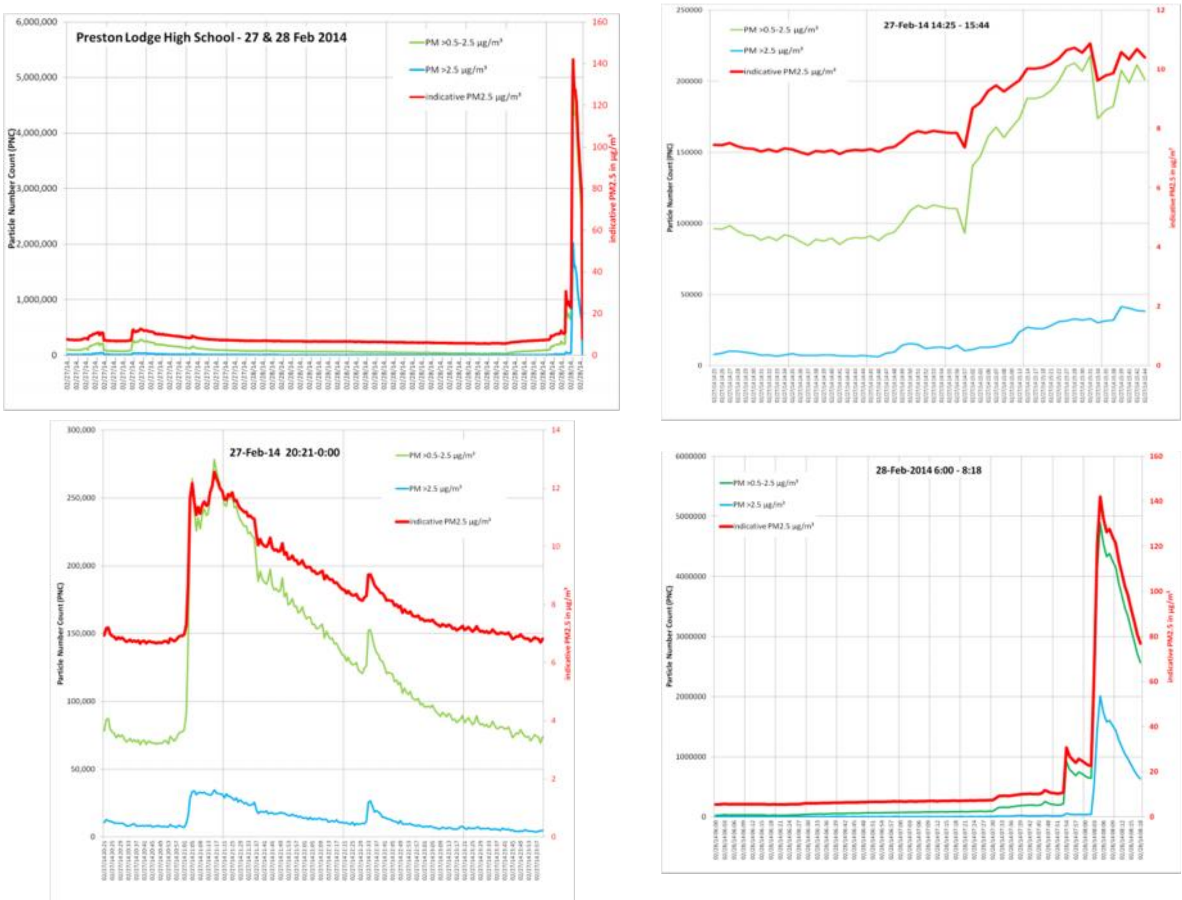


Fig. 2. Measurement results from Preston Lodge High School on 27th and 28th of February 2014

2.3 Mobile Monitoring – Glasgow Bike Station & SPOKES Edinburgh

Glasgow Bike Station

As noted above, contact with the Glasgow Bike Station was made through their work with Transport Scotland. They had already carried out some monitoring and were highly motivated to participate in the pilot study. This made preliminary engagement with the group straightforward. The monitoring pack and instructions were introduced and handed over to the volunteers on 12th of February 2014, with the main aims and objectives discussed in detail. Operation of the particle counter and the GPS receiver were explained and the rationale for logging time-activities as much as possible elaborated. Fig. 3 displays the maps resulting from 5 days of monitoring for short trips across Glasgow city centre, including commuting to and from work by bike, as well as other activities. The bottom right tile of the figure displays all recorded indicative PM2.5 concentration values (including those without GPS location information) and in comparison preliminary data from the Glasgow Kerbside fixed monitoring site for the same period, all values provided in µg/m³.

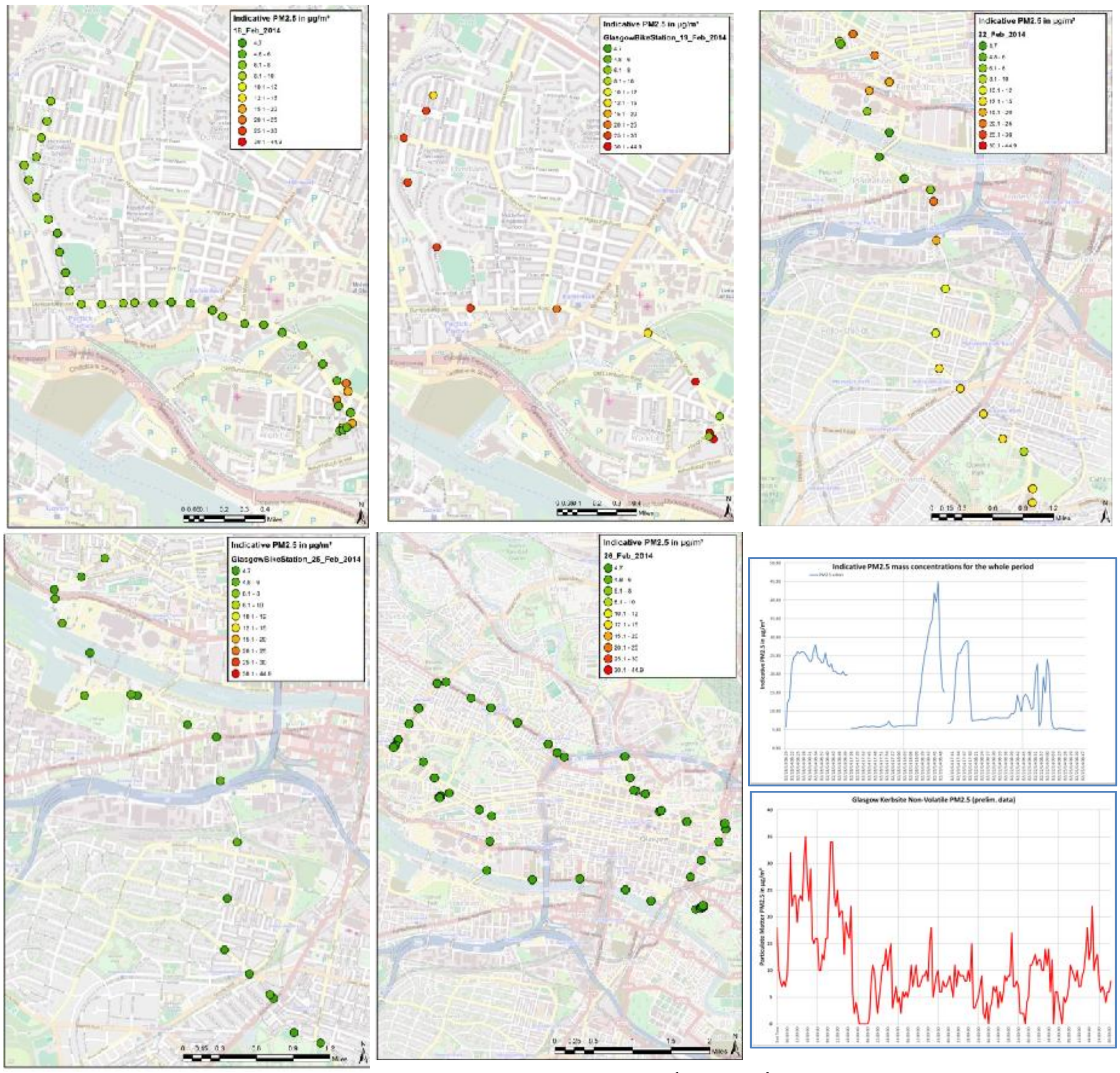


Fig. 3. Glasgow Bike Station volunteers monitoring between 18th and 26th of February 2014 and summary graph for the whole period in comparison to preliminary fixed monitoring data from Glasgow Kerbside

The monitoring pack was picked up on 26th of February with a visit to the Glasgow Bike Station base and verbal feedback received (see evaluation in Section 3). After data processing, another face-to-face meeting was held on 20th of March, presenting the monitoring results and further discussing the experience of using the pack, including barriers and potential improvements.

SPOKES Edinburgh

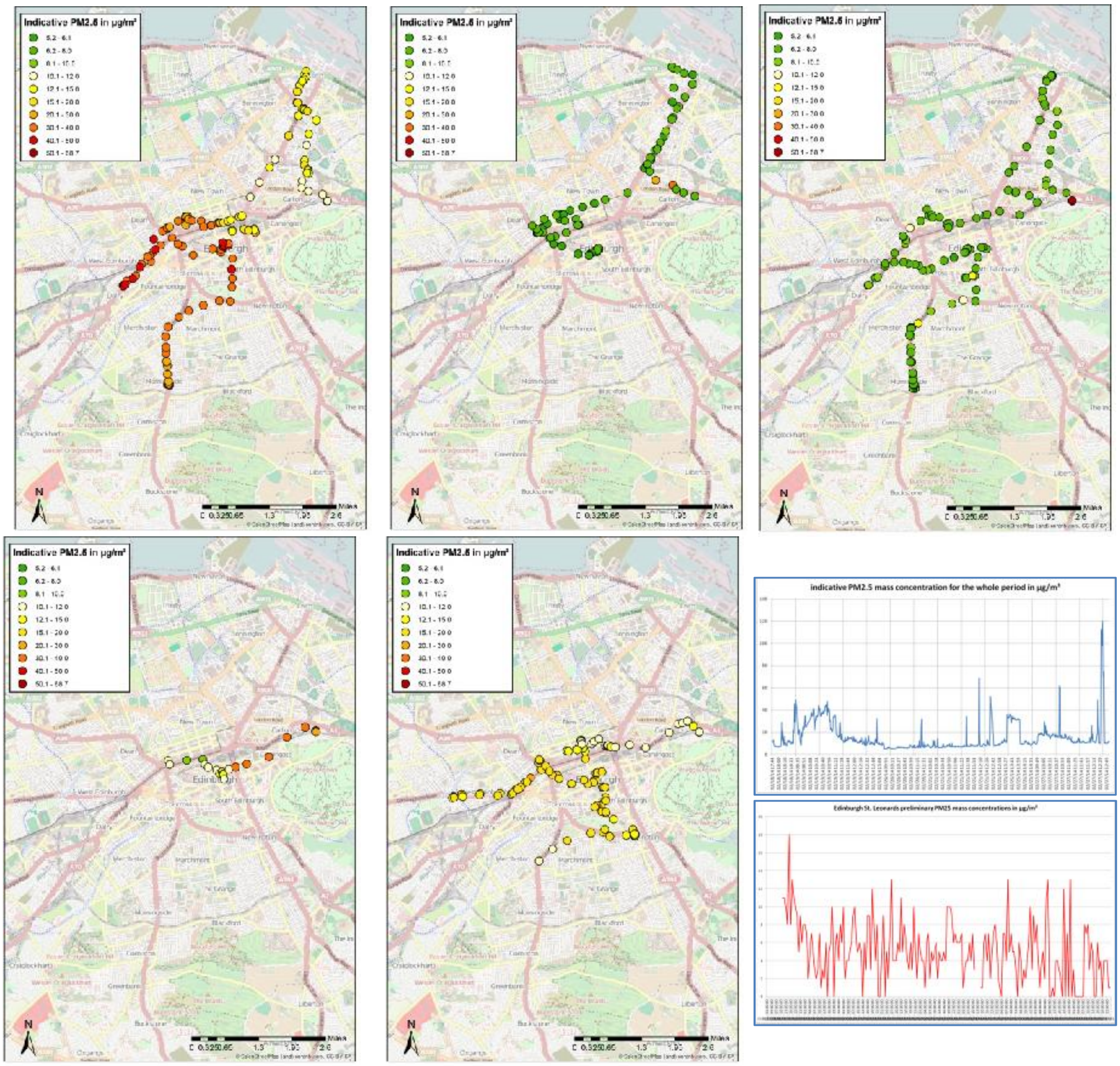


Fig. 4. SPOKES Volunteer 1 monitoring between 19th and 27th of February 2014 and summary graph for the whole period in comparison to preliminary fixed monitoring data from Edinburgh St. Leonards

The initial contact to SPOKES, the Lothian Cycle Campaign, had been made through Kim Harding, who supported the engagement and connected us with two volunteers, both working in a cycling context as bike couriers and delivery drivers, spending a substantial amount of time cycling across the Edinburgh city area. Monitoring activities were conducted between 19th of February and 12th of March 2014, with detailed results illustrated in Figs. 4 and 5, following the same layout as for Glasgow Bike Station. With both volunteers, the first contact was face-to-face, including the explanation of the monitoring pack, operation of the devices and taking notes with the time-activity-diary. After pick-up in town, or dropping off the monitoring pack at the Centre for Ecology & Hydrology, data processing and analysis was conducted analogue to the approach taken for the Glasgow Bike Station and explained to the volunteers in a face-to-face meeting.

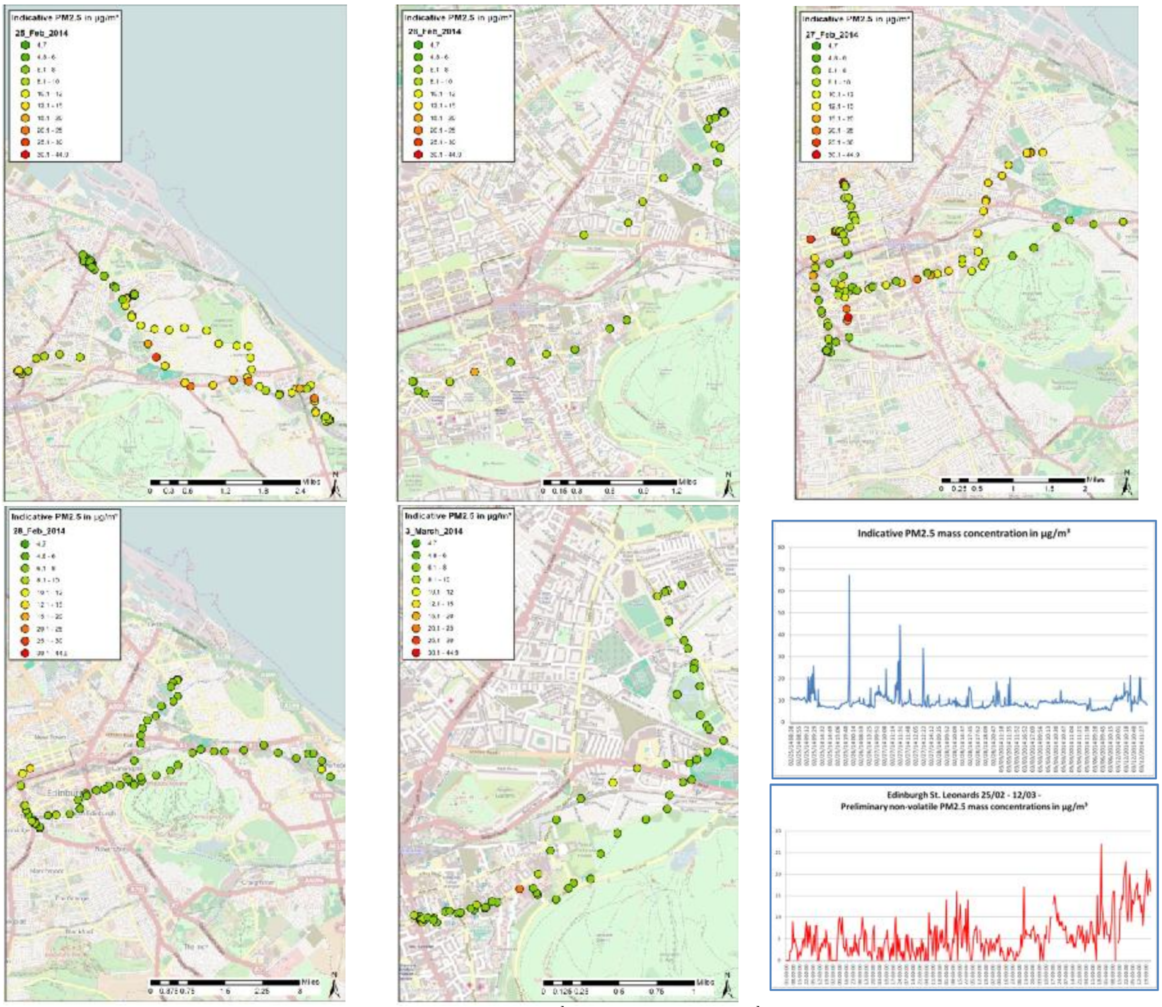


Fig. 5. SPOKES Volunteer 2 monitoring between 28th February and 12th of March 2014 and summary graph for the whole period in comparison to preliminary fixed monitoring data from Edinburgh St. Leonards

For all data collected by volunteers, substantial day-to-day variability can be observed, both represented in the monitoring data from the mobile monitors and the preliminary data from fixed monitoring sites, which affect concentrations across the domain. In addition, however, the observations from the volunteers illustrate how location and time of day have a measurable effect. Both average and maximum concentrations can be substantially above urban background or kerbside values at local hotspots or during rush hour conditions. However, the data from Glasgow Kerbside and Edinburgh St. Leonards fixed sites are currently only available as preliminary data and have not undergone the QA/QC process, which at times leads to significant changes in the final values, so any comparison at this time needs to be approached with caution. Keeping in mind that the Dylos 1700 is designed for stationary, indoor use, previous tests with using it in transit did not reveal any measureable influence of wind or movement, however, this should be thoroughly tested and taken into account for the development of a bespoke air pollution sensor for mobile applications.

The pilot study identified, respectively confirmed, caveats of the approach taken, for instance highlighting that GPS tracking coverage is generally incomplete due to signal loss indoors and in street canyons/near high buildings. Across all profiles recorded, GPS data was patchy, resulting in incomplete mapping information. One particle counter developed a fault during the final stage of monitoring with Glasgow Bike Station, resulting in total data loss (recording zero particle numbers) for part of the 25th and all of the 26th of February 2014. Further caveats related to the handling of the devices are discussed in detail in Section 3.

3 Evaluation

3.1 Volunteer feedback

The feedback from the cyclists was overwhelmingly positive on the overall ability to using a personal device to monitor personal exposure to air pollution, as the awareness of individuals spending a substantial amount of their daily activities in traffic and an urban outdoor environment of air pollution is very high.

Specific feedback on the handling of the monitoring pack highlighted the encumbrance-factor as one of the key aspects. Bike couriers and cyclists transporting goods often carry backpacks or delivery bags, making it difficult if not impossible to handle another backpack. In addition, the size and weight of the backpack, albeit comparatively small, presents a barrier to using it without planning or testing different ways to carry it. The lack of ruggedness or weatherproof design resulted in several opportunities of use not being realised due to rain, as even intermittent rain showers meant that the equipment either needed to be covered or left indoors. Operating both the particle monitor and the GPS independently was perceived as cumbersome, leading to potential gaps in collecting location information due to switching the GPS on too close to starting a journey, or forgetting to switch it on.

A specific comment made by all volunteers is that they would like to view their results en route and/or online to be able to react to high values or inform decisions on routing etc. In connection to this, the logging of time-activity information was perceived as challenging, in particular in a work environment, when other activities required attention. However, time activity data is an essential contextual information source, as even when a GPS receiver accurately tracks all movements, specific local context and activities can only be adequately tracked and inform the interpretation of the monitoring results if this data is available. For both aspects, integration with a mobile phone, for instance to display current concentration values, as well as to prompt the recording of time-activity data at regular time intervals through a mobile app was perceived by the volunteers as having substantial potential to improve the experience and facilitate data logging.

3.2 Survey results

All participants were asked to complete Evaluation Surveys (Annex A).

School pilot

Two questionnaires were returned by staff at the school, one member of staff who had been involved only early in the pilot study and one member of staff who had participated throughout the pilot study. They were interested to participate in the study because they thought it looked interesting and would link to either the science or the geography curriculum. In the course of the pilot, they decided it linked best with geography, particularly fieldwork and course content for the new National and Higher courses, covering pupils aged between around 14 and 17.

Training was thought to be adequate and use of the equipment and diary completion was ‘quite easy’. However they found it ‘a little difficult’ to submit the data. They enjoyed participating in the project but would have liked more time to carry out data collection. For direct access to the data, a display of the data logged (currently, the Dylos 1700 is set up to display "Logging data" only to avoid strategic behaviour of pilot study participants when observing high concentrations). They would also be keen to have access to the mobile set-up with the backpack and GPS logger. It would also be beneficial to have time with the pupils for them to design their own experiments and fieldwork. As noted above, there were issues in retrieving data from the sensor and so feedback has been limited and it has not been possible to fully evaluate the pilot as a learning experience. Nonetheless, it was felt that the study had resulted in greater participation in fieldwork, increased awareness of sampling and contextualisation of the topics studied.

One member of staff noted that they were, and always are, pushed for time and that full participation in work of this kind would have to be factored into their year early on to get the most out of it. This may have been a particular issue with the age group of pupils involved in the pilot study, where there would have been a strong focus on preparation for the Scottish Qualification Authority spring examinations. Involvement of younger pupils, including those at primary schools, may mitigate this concern.

For future development of this kind of activity, it was suggested set experiments involving data collection could be produced that would be made available for schools to use. The current method/format of data presentation is a little daunting for pupils with limited science knowledge and different presentation methods could be considered.

Cycling pilot

Four participants from the cycle pilot completed the survey.

The cyclists got involved in the project because they were interested in learning more about pollution (one respondent mentioned personal asthma); also because they saw participation as straightforward given that they were cycling regularly.

Training was considered adequate, with recommendations that a trial run or further time to familiarise oneself with the kit would be of use. One respondent noted that they were unsure whether the GPS was working or not.

All participants considered it ‘quite easy’ to use the equipment and submit the data. Most found the diary easy to use, with the exception of one participant who found it difficult.

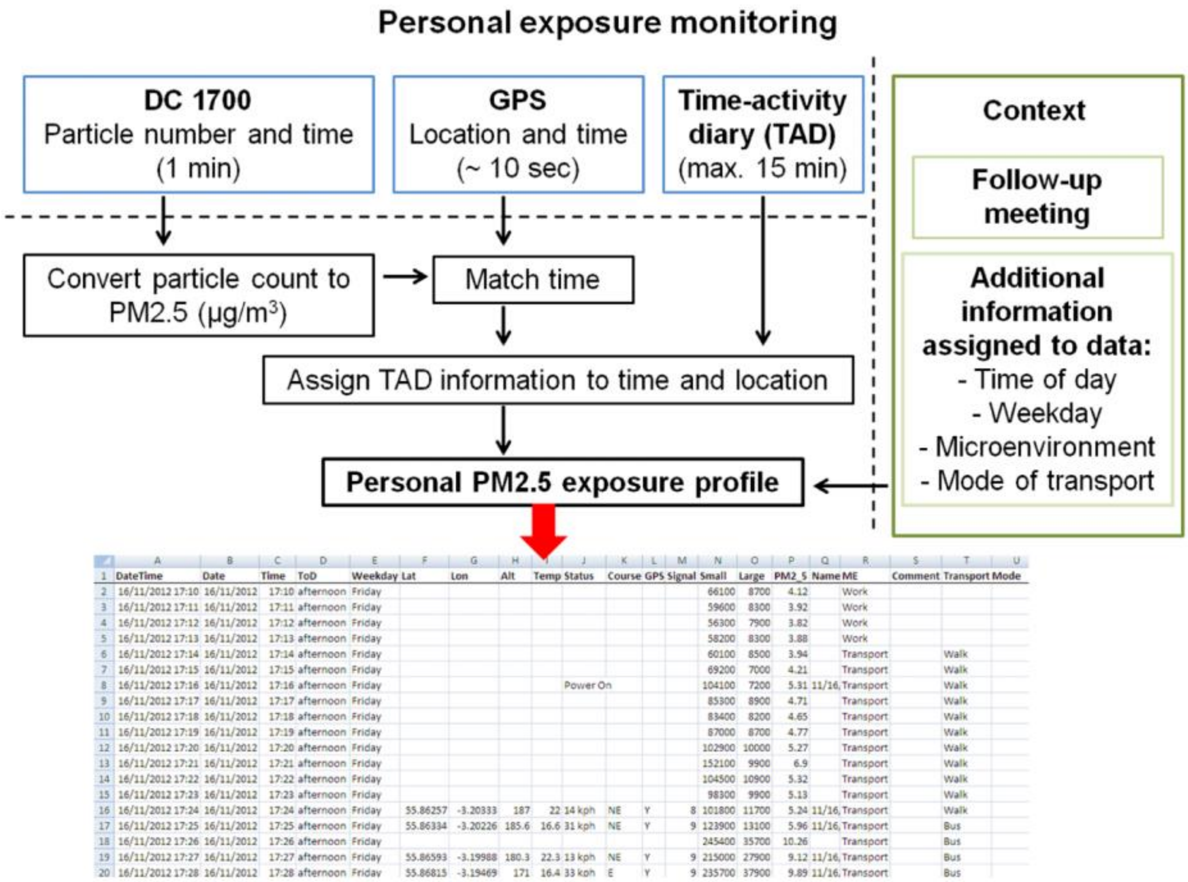
All participants enjoyed participating in the project. Making the equipment less heavy, bulky and awkward to carry alongside other bags was seen as an important factor in improving the experience for cyclists. It was noted by one participant that less devices to charge would have made it more enjoyable. Another identified the potential to compare journeys and spend more time with the monitor being a factor in improving enjoyment of the experience.

Participants felt that they learned through participating in the project, one mentioned ‘some interesting facts and statistical data about small particles of pollutants and what causes them’. They also felt that there had been changes in their lives as a result of participating including greater awareness of air pollutants; ‘ I am thinking more about the routes that I choose, I don’t beat myself up for choosing an off road route sometimes to avoid a particularly busy junction; before I just thought about getting from a to b as fast as possible!

3.3 Pilot team observations

The volunteer feedback confirmed the observations and limitations identified by the pilot study team in the phase 1 report on available air pollution monitors for mobile personal exposure sensor application. In addition, the engagement with volunteers and the manual data handling and evaluation process are time consuming and can only be done in the current fashion for a limited pilot study. The engagement with the school was not straightforward and corresponds with previous observations from the Scotland Counts Schools working Group. Despite the teachers' initial enthusiasm for participation in the project, it was extremely difficult to contact them. The extra burden on teachers' time and the difficulty in linking the monitoring activity into already planned learning timetables appear to have been a factor in the limited context in which the equipment was used in the school during the pilot phase.

Fig. 6 illustrates the different steps required to merge data from the GPS receiver and the Dylos 1700 particle monitor, including using time-activity diary information to enrich the dataset for the evaluation process. An additional step not illustrated is the generation of maps (and ultimately movies) to communicate accessible visual information to volunteers.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	DateTime	Date	Time	ToD	Weekday	Lat	Lon	Alt	Temp	Status	Course	GPS	Signal	Small	Large	PM2_5	Name	ME	Comment	Transport	Mode
2	16/11/2012 17:10	16/11/2012	17:10	afternoon	Friday									66100	8700	4.12		Work			
3	16/11/2012 17:11	16/11/2012	17:11	afternoon	Friday									59600	8300	3.92		Work			
4	16/11/2012 17:12	16/11/2012	17:12	afternoon	Friday									56300	7900	3.82		Work			
5	16/11/2012 17:13	16/11/2012	17:13	afternoon	Friday									58200	8300	3.88		Work			
6	16/11/2012 17:14	16/11/2012	17:14	afternoon	Friday									60100	8500	3.94		Transport		Walk	
7	16/11/2012 17:15	16/11/2012	17:15	afternoon	Friday									69200	7000	4.21		Transport		Walk	
8	16/11/2012 17:16	16/11/2012	17:16	afternoon	Friday					Power On				104100	7200	5.31	11/16,	Transport		Walk	
9	16/11/2012 17:17	16/11/2012	17:17	afternoon	Friday									85300	8900	4.71		Transport		Walk	
10	16/11/2012 17:18	16/11/2012	17:18	afternoon	Friday									83400	8200	4.65		Transport		Walk	
11	16/11/2012 17:19	16/11/2012	17:19	afternoon	Friday									87000	8700	4.77		Transport		Walk	
12	16/11/2012 17:20	16/11/2012	17:20	afternoon	Friday									102900	10000	5.27		Transport		Walk	
13	16/11/2012 17:21	16/11/2012	17:21	afternoon	Friday									152100	9900	6.9		Transport		Walk	
14	16/11/2012 17:22	16/11/2012	17:22	afternoon	Friday									104500	10900	5.32		Transport		Walk	
15	16/11/2012 17:23	16/11/2012	17:23	afternoon	Friday									98300	9900	5.13		Transport		Walk	
16	16/11/2012 17:24	16/11/2012	17:24	afternoon	Friday	55.86257	-3.20333	187	22	14 kph	NE	Y	8	101800	11700	5.24	11/16,	Transport		Walk	
17	16/11/2012 17:25	16/11/2012	17:25	afternoon	Friday	55.86334	-3.20226	185.6	16.6	31 kph	NE	Y	9	123900	13100	5.96	11/16,	Transport		Bus	
18	16/11/2012 17:26	16/11/2012	17:26	afternoon	Friday									245400	35700	10.26		Transport		Bus	
19	16/11/2012 17:27	16/11/2012	17:27	afternoon	Friday	55.86593	-3.19988	180.3	22.3	13 kph	NE	Y	9	215000	27900	9.12	11/16,	Transport		Bus	
20	16/11/2012 17:28	16/11/2012	17:28	afternoon	Friday	55.86815	-3.19469	171	16.4	33 kph	E	Y	9	235700	37900	9.89	11/16,	Transport		Bus	

Fig. 6. Data processing of mobile monitoring data (based on Steinle *et al.*, 2014)

This manual data processing and the engagement process with individual volunteers requires staff time resources in the order of 5-10 hours per volunteer and monitoring period, depending on location and amount of data to process, respectively the quality and visual appeal of the evaluation material produced, this could be substantially higher even. With the current equipment, there is no straightforward approach to simplify the data processing, as the time-stamp matching, analysis and generation require manual intervention. On the other hand, mobile applications or processing environments (e.g. the OpenAir package for the R statistical software) could offer an automatic processing environment in conjunction with a more integrated sensor package.

3.4 Data feedback and visualisation

The evaluation of the pilot studies, and other work on citizen science projects, shows that participants are keen to have real-time feedback on the data they are collecting. Within the current study, the cyclists participating in the pilot study commented that "they would like to view their results en route and/or online to be able to react to high values or inform decisions on routing" while staff at the school felt that "the current method/format of data presentation is a little daunting for pupils with limited science knowledge".

The volume and nature of datasets themselves can vary greatly, much affecting the ease with which they can be transmitted, analysed, interpreted and understood by the end user. There are several issues which need to be taken into consideration in the feedback of data to citizen science volunteers:

- Rates of data collection in citizen science can vary greatly – collection may be virtually constant, such as one measurement per second or more frequent, involving multiple streams of data (eg time, location, humidity, particulate level), synchronously; data may be collected more periodically (eg time, temperature and humidity every 30 seconds); data may be relatively few and intermittent, in discrete survey records or observations (eg species, date-time, location, other contextual survey data);
- Sensors can generate huge amounts of data in a relatively short time period which needs to be processed before presentation to participants;
- Depending on the sophistication of the sensor, or associated equipment, currently some "real time" data, especially that involving multiple streams of data needs to be pre-processed to normalise and integrate the data before analysis and presentation;
- Some sensor data will need to be 'calibrated' and quality assured before presentation;
- Decisions need to be made about whether the data will be made available only to study participants or will be publicly available;
- Decisions need to be made regarding the format in which data will be made available e.g. raw data, summarised data, mapped data.

Real-time data feedback

Sensor technology

To produce real-time feedback to users, sensors have to have built-in communication to a means of displaying data. This can be through connection to a smartphone app, by using Wi-Fi to communicate with the web or using a sim card within the sensor to communicate with a hub which can then transmit the data to a smartphone or web page. An example is the Net-Amo weather station that uses a Wi-Fi connection to display real-time readings of variables such as noise, temperature and humidity on a webpage - a link to which can be made available to as many or as few individuals as required.

However, recent work with primary schools has shown that linking into Wi-Fi networks in an educational establishment can be difficult to achieve. Within the CITI-SENSE project, an indoor air sensor is being developed which uses a built-in sim card to send data to a hub which is then summarised and displayed in close to real-time on a website in a user-friendly format. The readings from this sensor can also be displayed within other websites using an embeddable web widget.

Contextual data

There are many websites available or in development which allow either the project team or the study participants to design simple questionnaires to record contextual or observational data. Links to these questionnaires can be via QR codes, web widgets and/or Facebook apps. Responses to these questionnaires can be viewed in summarised form on the websites as soon as the data are received, rate and numbers of responses can also be tracked over time. Some of the websites can report the data in mapped format, usually based on GIS data from smartphone data entry, for example the EpiCollect website in the SEWeb toolkit.

Scotland's Environment (SEWeb)

Scotland's Environment provides a comprehensive website that provides in one place the most current assessment of the state of the environment in Scotland. In addition to a range of data on environmental indicators including air quality, land use, bathing water, waste sites and greenspace, the website also encourages the general public to become involved in Scotland's environment through environmental projects and through provision of a toolkit that pulls together several freely available resources for use in citizen science projects.

The tools within the SEWeb toolkit are divided into three subcategories – Identification Tools Collation Tools, and Infrastructure Tools. The three identification tools are specifically designed for recording instances of specific flora or fauna. PlantTracker is an app which enables the recognition and geo-location recording of invasive non-native plant species. Leafsnap is a mobile app to help identify tree species from photographs of leaves. Neither of these are likely to be used in an air quality citizen science project. The third identification tool is iSpot. This is a more flexible app for the identification of a wide range of wildlife observations including plants, fungi and lichens. It could be useful for the recording of observations of natural indicators of air quality such as lichens.

Within the collation tools iRecord provides similar functionality to iSpot and may also be useful in recording natural indicators of air quality. It also provides the facility to provide summaries of each user's records by 'group' (i.e. flowering plant, lichen, conifer, dragonflies) and of all records by 'group' in tabular, graphical and mapped formats.

The other two tools in the collation tool group are data collection tools – Open Data Kit (ODK) and EpiCollect. Both of these tools allow the user to design data collection forms or surveys which can then be used to collect the requested data via mobile phone. Data are then collated from the mobile phones via a server. ODK runs on Android devices only and ODK Aggregate can be used to visualise the collected data using maps or simple graphs and export data to spreadsheets and csv files. EpiCollect runs on Android and iPhone devices and the data collected are then stored on a central website and can be viewed using Google maps, tables and charts or downloaded for further analysis. These two tools are unrestricted on the data that they can collect which depends solely on the user's data collection form design. They could be useful for collecting real time contextual data (e.g. weather conditions, traffic density) related to air quality projects but would not be suitable for processing the real time measurement data from sensors.

The third group of tools, infrastructure tools, are more advanced and require some IT expertise to implement. For one of these sites – Geoserver – we were unable to access the site directly, getting an error message, but we were able to access the case study pages that used the tool. Four of the five tools are mapping tools that use open source Geographic Information Systems (GIS) to map data on any topic. Ushahidi appears to be primarily used by activists, news organisations and large companies such as World Bank and the United Nations. It uses crowd sourcing methods to gather data and information from text messages, email, twitter and webforms. OpenLayers and QGIS provide mapping functionality that can embed a map widget within web pages. To use these sites requires knowledge about GIS data e.g. vector data and and raster data.

The tool most relevant to air quality citizen science projects in the infrastructure group is the Open Air project, a Natural Environment Research Council (NERC) knowledge exchange project. This project provides open-source tools specifically for the analysis of air pollution data. The analyses are based in the free statistical software package 'R' and Open Air is made available as a package that can be loaded into the R software. To use Open Air some knowledge of the R package is required and the Open Air manual provides a general introduction to this. The tool can provide some detailed analyses of air quality data including trend analyses and model evaluation. Measurement data downloaded from sensors used in air quality citizen science projects could be loaded into the R software and analysed using the Open Air tools. Like the other tools in the SEWeb toolkit, real time data analysis and feedback would not be feasible.

4 Conclusions

As indicated in the previous section, the key challenges and potential caveats related to the non-availability of integrated sensors at this point in time have been confirmed by the pilot studies. This relates to both the form factor and operational aspects of the devices used in the mobile pilot deployment, and the potential for operator errors or device malfunctions which are not picked up as there is no direct feedback to the user.

User engagement is a key aspect. It is of note that the cyclists participated in the project because they saw clearly how it related to their interests and fitted simply into their existing daily activities. Though there are clear links between air quality monitoring and Curriculum for Excellence, the effective engagement of schools, particularly at secondary level, requires a long term engagement process and sustained support throughout the project period.

Tied in with the development of more accessible and robust devices, the training needs for citizen scientists, as well as the reduction of manual, one-off data processing would need to receive a high priority.

The visualisation of results in both accessible, simple graphs and in a geospatial and temporal context, using maps and animations would likely further add value for lay people to interpret their own results. Integration with popular communication or mapping platforms such as Twitter or Google Maps would reduce the need for the development of bespoke software solutions for processing, display and interpretation of data. Mobile devices, which are ubiquitous today, should be considered as means to manage sensor devices and for data transfer to a central hub for processing and display.

Volunteers who took part in the cycle pilot study were very enthusiastic and expressed interest in further engagement should a wider citizen science project to monitor air quality be implemented. This is partly driven by general interest in environmental aspects, and partly due to personal circumstances, e.g. spending a substantial amount of time on bikes in urban areas, or suffering from asthma or other respiratory diseases and experiencing direct health effects due to exposures to air pollution levels that are not perceived in the same way by the general population.

Direct engagement activities outside of this pilot study, following media coverage of the backpack studies conducted by CEH, have led to further citizens using the packs to monitor air pollution around their home (in the context of wood stove emissions in a residential neighbourhood) and in the Greater Glasgow area (in the context of an asthma sufferer aiming to relate symptoms to high particulate matter concentrations) are under way and will be evaluated shortly.

Tools available on the web and summarised in the toolkit provided on Scotland's Environment website provide useful functionality for the collection and processing of air quality citizen science data. Particularly relevant to these projects are iSpot and iRecord for recording natural observations relevant to air quality (e.g. lichens); ODK and EpiCollect for the collection and display of contextual data and Open Air for the analysis of air quality measurement. However, none of these tools provide the real-time data processing and feedback that many citizen science participants would prefer and to do this would require the use of more sophisticated (and expensive) sensors with built-in communication facilities such as Wi-Fi, Bluetooth or sim cards.

5 References

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6 ANNEX

6.1 ANNEX A - Post-evaluation questionnaire for volunteers

Please tell us about your experience of being involved in the Air Quality pilot. Each person involved in the programme should complete a separate form.

1. Tell us a bit about yourself:

Age		Gender		Occupation	

2. Why did you get involved in the pilot project?

3. What was your role during the pilot project? Tell us what you did.

4. Was the training and information provided before the project adequate? Yes

No

Tell us how it could have been improved.

5. Tell us about your experience of participating in the project

	Easy	Quite easy	A little difficult	Difficult
How easy was it to use the equipment?				
How easy was it to complete the diary?				
How easy was it to submit the data?				

Did you enjoy participating in the project? Yes No

Tell us how the project could have been more enjoyable.

6. Was the feedback provided after the project adequate? Yes No

Tell us how the feedback could have been improved.

7. What did you learn from participating in the project?

8. Tell us what has changed for you and your school or group as a result of participating in the project

9. Please tell us anything else that would be useful to help us develop this activity for wider use.

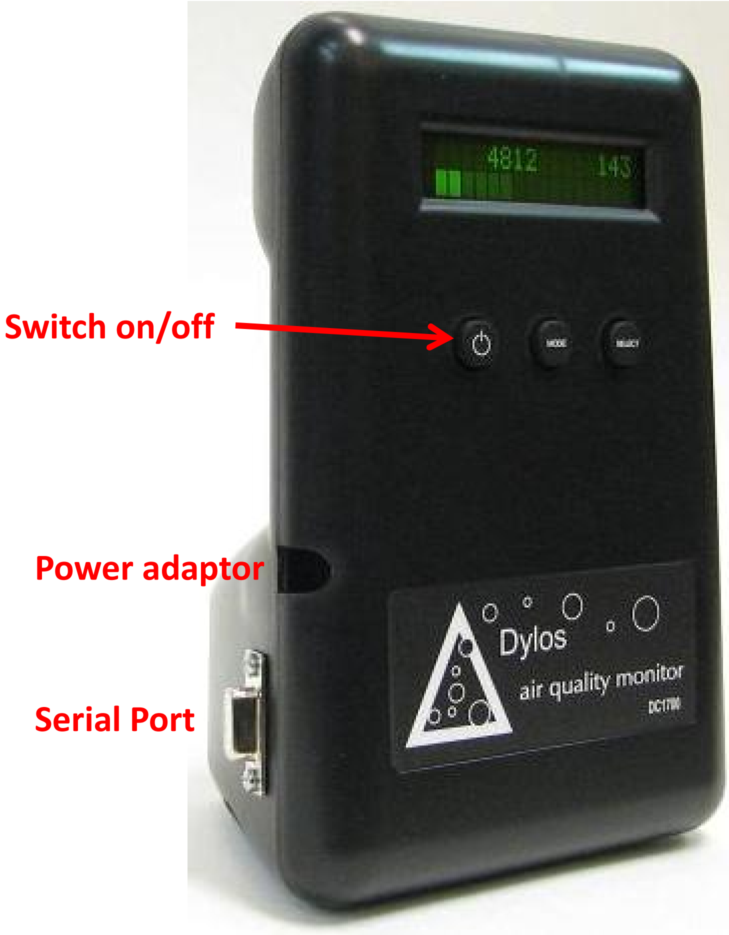
Many thanks for completing this evaluation.

6.2 ANNEX B - User guide for air pollution monitor and GPS receiver

Dear volunteer,

Thank you for taking part in our pilot study on citizen science applications for air quality monitoring.

Some useful information on handling the particle monitor (Dylos 1700), GPS (Trackstick) and time-activity notes:



Particle Monitor:

The Dylos 1700 has originally been designed for indoor use. Please do not use the device when it rains, as water may damage the electronics! On a rainy day you may still use it indoors, but keep it dry when moving around outdoors
.

Once you arrive at home you can place the whole backpack somewhere central near a socket so the **particle counter** can be recharged and run on mains power overnight e.g. in your living room or the kitchen. This important as the battery lifetime is approximately 6 hours!

PLEASE CHARGE OVER NIGHT OR WHEN THE DYLOS IS STATIONARY FOR SOME TIME

http://www.dylosproducts.com/dc1700.html

GPS:

The GPS Unit needs some time to get a fix on satellites after it is switched on, so best switch it on some time before you are starting a journey.

Once you arrive in a building where you will stay for a certain time (e.g. work, home etc.) you can switch the **GPS** off and switch it on again once you leave the place (this will conserve battery power and typically, GPS sensors do not track well, if at all, indoors). Please note these times in your diary.

- Please leave the **GPS** switched on when you go to a shop etc. for a short period of time only.
- If you want to know more about the device - the link to the GPS Trackstick manufacturers website is here: http://www.trackstick.com/products/supertrackstick/index.html
- Please **take notes** about your whereabouts and activities including rough times! Attached is a short schema for noting your main activities (time spent indoors or outdoors, in different transport modes, general observations) which will help in the processing of the time and activity data afterwards.
- We will ask you as well to fill a questionnaire once to gather general information e.g. on your home or other places you spend time to put the measured data into context.

6.3 ANNEX C - Template for Time-Activity-Diary

Date:				
Hour	**Notes**		**Hour**	**Notes**
01:00			13:00	
02:00			14:00	
03:00			15:00	
04:00			16:00	
05:00			17:00	
06:00			18:00	
07:00			19:00	
08:00			20:00	
09:00			21:00	
10:00			22:00	
11:00			23:00	
12:00			00:00	