Norsk institutt for luftforskning
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# Oslo Citizens' Observatory

## Results from the CITI-SENSE Oslo Empowerment Initiative

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ABSTRACT

The CITI-SENSE project has been created to develop Citizens' Observatories in different cities in Europe. By using a variety of low-cost sensors, citizens should be empowered to influence community policy and decision making in the area of air quality. In the framework of this project, we carried out different case studies (Empowerment Initiatives – EIs) in the fields of Urban Air Quality, Public Spaces and School Indoor Air Quality in the following nine cities: Barcelona (Spain), Belgrade (Serbia), Edinburgh (UK), Haifa (Israel), Oslo (Norway), Ostrava (Czech Republic), Ljubljana (Slovenia), Vienna (Austria) and Vitoria-Gasteiz (Spain).

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NORWEGIAN TITLE

Oslo Citizens' Observatory: Klarte vi å styrke innbyggernes mulighet til å påvirke luftkvaliteten i Oslo?


KEYWORDS

Air quality | Citizen participation | Low cost sensor network



ABSTRACT (in Norwegian)

CITI-SENSE prosjektet har blitt initiert for å etablere såkalte Citizens' Observatorier i forskjellige byer i Europa. Ved å bruke forskjellige lavpris måleinstrumenter skulle folk flest bli i stand til å påvirke beslutningene som berører luftkvaliteten i deres nærområder. Som del av CITI-SENSE gjennomførte vi undersøkelser i ni europeiske byer. Denne rapporten inneholder resultatene fra aktivitetene gjennomført i Oslo Citizens' Observatoriet, aktiv i tidsrommet mellom desember 2015 og september 2016. Vi presenterer verktøy og tjenester vi brukte, innsamlede data og målinger samt brukernes vurdering av verktøyene og aktivitetene i Oslo. Vi avslutter med å presentere våre erfaringer fra aktiviteter som hadde som mål å engasjere befolkningen i miljøovervåkning.



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# Preface

The CITI-SENSE project was created to develop Citizens' Observatories in different cities in Europe. Aided by using a variety of low-cost sensors, citizens should be empowered to influence community policy and decision making in the area of air quality. In the framework of this project, we carried out different case studies (Empowerment Initiatives – EIs) in the fields of Urban Air Quality, Public Spaces and School Indoor Air Quality in the following nine cities: Barcelona (Spain), Belgrade (Serbia), Edinburgh (UK), Haifa (Israel), Oslo (Norway), Ostrava (Czech Republic), Ljubljana (Slovenia), Vienna (Austria) and Vitoria-Gasteiz (Spain).

This document reports the results from the activities within the Oslo Citizens' Observatory, carried out between December 2015 and September 2016. In this report, we present tools that have been used, results based on the data we collected and measurements that were taken. We also present the users' evaluation of the tools and the project activities in Oslo. In the concluding remarks, we summarize our experiences and lessons learned for engaging the public in environmental monitoring.

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# Summary

Air pollution poses a threat to human health, and the WHO has identified air pollution as the world's largest single current environmental health risk. In Europe, the majority of the population lives in areas where air quality levels frequently exceed WHO's ambient air quality guidelines, and many live in areas that are not in compliance with European legislation.

The CITI-SENSE project[1] has been created to develop Citizens' Observatories[2] in different cities in Europe. Oslo was one of the 9 participant cities. In order to engage with citizens and empower them to participate in environmental governance, the project created various tools and products that have been used in the different project locations. The tools included:

i. Static sensor platforms: a total of 64 static monitoring platforms have been deployed at different sites in the city of Oslo, including in 51 kindergartens. The platform measured four gaseous components (CO, NO, $NO_2$ and $O_3$) and particulate matter ($PM_{10}$ and $PM_{2.5}$).
ii. Personal air quality monitoring toolkit: a mobile sensor unit is connected via Bluetooth to a mobile phone. The sensor platform measured NO, $NO_2$ and $O_3$. A total of 32 volunteers participated carrying the mobile sensor unit in their daily commuting.
iii. Data visualization portal: the data collected by the sensor nodes (static and mobile) was published in a web portal as an Air Pollution Indication (APIN), using a 5 colour scale.
iv. On-line air quality perception questionnaire: the tool was created for collecting and analysing how the user perceives air quality issues. We obtained questionnaires from 332 participants.
v. CityAir Smartphone App: CityAir is a smartphone application to provide information about people's personal perception of the outdoor air quality right where they are. The app is available for free through Google Play and Apple Store. A total of 316 reports were collected.

We have carried out different measures to obtain feedback from the users on the tools that have been used in the CITI-SENSE activities in Oslo, including an online questionnaire on the usability of the products, focus groups and interviews.

CITI-SENSE has involved people in testing new technologies that will be employed in the near future to monitor air pollution. We have seen that the technology used in CITI-SENSE to monitor air pollution, is still in an early stage of development. This means that the data we obtained cannot be used directly by the citizens due to their high uncertainty. In general, the data we obtained requires complex data analysis that can only be carried out by experts. Nevertheless, this project has also demonstrated the big potential that lies within the new sensor technology.

In CITI-SENSE, we not only focused on testing new technology, but also on understanding how people in Oslo perceive outdoor air quality. The results showed that the participating citizens are very interested in air quality, and most of them think that air quality is affecting their

[1] CITI-SENSE – Development of sensor-based Citizens' Observatory Community for improving quality of life in cities. EU FP7 funded research project; www.citi-sense.eu/ and http://co.citi-sense.eu

[2] The term Citizens' Observatory describes a concept where citizens are empowered to contribute to environmental decision-making through their own observations. Usually, a sophisticated ICT system supports citizens in reporting their observations, and enables communication and exchange with authorities and other citizens.

health. Despite that fact, the results show that almost half of the respondents do not consider air quality levels at all or very little when moving in the city and that they actually do not look at air quality information on a regular basis.

When visualizing and communicating data or results, we have to ensure that people actually understand what the data are about and what they mean for the environment, people's daily life and their and the health of the person's familiy.

# Oslo Citizens' Observatory. Results from the CITI-SENSE Oslo Empowerment Initiative

## 1 Introduction

Clean air is a basic requirement for human health and well-being. Although air quality has improved in recent years, air pollution continues to pose a significant threat to the environment and human health.

In Oslo, air pollution is in general low, but in some areas and during specific times air pollution concentrations can reach levels that are harmful for the population, especially for sensitive groups (i.e., children, pregnant, elderly, asthmatic and people with respiratory and heart diseases).

In Oslo, air quality information is publicly available through a website (www.luftkvalitet.info). Information on the air quality status monitored by 12 air quality stations is updated every hour during the whole year. Traditional stationary air quality monitoring stations are fundamental tools in the management and research of air pollution. They are equipped with certified air quality monitors and subjected to strict routines of maintenance and calibration to ensure high data quality and comparability between different regions. However, due to the high cost of maintenance, only few of them can be installed in a city.

The emergence of low-cost, user-friendly and very compact air pollution platforms (micro-sensors) allowing observations at high spatial resolution in near-real-time, provides us with new opportunities to simultaneously enhance existing monitoring systems as well as enable citizens to engage more actively in environmental monitoring.

The CITI-SENSE project[3] was created to develop Citizens' Observatories[4] in different cities in Europe. By using a variety of micro sensors, citizens should be empowered to influence community policy and decision making in the area of air quality. In the framework of this project, we carried out different case studies (Empowerment Initiatives – EIs) in the fields of Urban Quality, Public Spaces and School Indoor Quality in the following nine cities: Barcelona (Spain), Belgrade (Serbia), Edinburgh (UK), Haifa (Israel), Oslo (Norway), Ostrava (Czech Republic), Ljubljana (Slovenia), Vienna (Austria) and Vitoria-Gasteiz (Spain).

A range of different technical equipment has been provided as one of the bases to create Citizens' Observatories in each of the participating cities. We have engaged with volunteers that helped us test the technical tools and products that have been designed for and within the CITI-SENSE project to empower citizens to participate in environmental governance. Furthermore, contact with local authorities has been initialised for citizens to engage in environmental decision-making.

[3] CITI-SENSE – Development of sensor-based Citizens' Observatory Community for improving quality of life in cities. EU FP7 funded research project; www.citi-sense.eu/

[4] The term Citizens' Observatory describes a concept where citizens are empowered to contribute to environmental decision-making through their own observations. Usually, a sophisticated ICT system supports citizens in reporting their observations, and enables communication and exchange with authorities and other citizens.

Low-cost sensor-based platforms are a technology still under development, however, showing promising results. As all developing technology, it still needs improvements and testing before it can be easily used in monitoring applications that require higher accuracy, precision and reliability.

As a complement to these novel sensor technologies, in the CITI-SENSE project we have also developed tools for people to contribute with their own perception about air quality.

This document reports results from the activities within the Oslo Citizens' Observatory, carried out between December 2015 and September 2016. In this report, we present tools that have been used, results from collected data and measurements and the users' evaluation of the tools and the project activities in Oslo. We wrap up with some concluding remarks and the lessons learned for engaging the public in environmental monitoring.

# 2 Some facts about Oslo and the Oslo air quality

Oslo city is the capital and the most populous city of Norway with 658 390 inhabitants in 2016 according to Statistics Norway. Most of the population is in the age range between 20-44 (44%) and 45-66 (24%), the distribution according to gender is 50% females and 50% males. Almost 50% of the population (considering 16 years old and older) has completed higher education.

The municipality of Oslo has an area of 130 $km^2$, and it is situated at the northernmost end of the Oslo fjord. The fjord lies at the south of the city, in all other directions Oslo is surrounded by wooded hills and mountains that reach over 400 m.a.s.l within Oslo limits. Oslo has a humid continental climate, which is highly influenced by the warm Gulf stream which makes the climate milder than at similar northern latitudes elsewhere over the globe. In summer, the daily mean temperature is around 16°C, and during winter is around -4°C (climate data for Oslo-Blindern station for the period 1961-1990). In January, three out of four days are below 0°C, and on average one out of four days is colder than −10°C.

During winter, on cold, clear days with low wind, Oslo often experiences the formation of thermal inversions, with a reversal of the normal decrease of air temperature with altitude. The warm air on the top holds down the cool air and prevents pollutants from rising and dispersing. The inversion layer can persist for several days, causing an increase in the pollution levels, exceeding, in some occasions, the air quality thresholds defined for human health protection.

Traffic, especially exhaust from high duty vehicles and private diesel vehicles and dust resuspension from studded tyres, together with wood burning in winter, are the main sources of pollution in Oslo. Emissions from ships and from the harbour also contribute to the pollution levels. The higher levels occur during winter, due to the adverse meteorological conditions, however particulate matter levels can also be high in spring, due to the use of studded tyres.

Norway, as part of the European Economic Area, is obliged to comply with the European air quality regulations (e.g., Directive 2008/50/EC) and ensure clean air. Nevertheless, Oslo exceeded both the annual and hourly $NO_2$ threshold for health protection defined in the Directive 2008/50/EC in 2015. The European and national thresholds for particulate matter ($PM_{10}$ and $PM_{2.5}$) were not exceeded in 2015.

# 3 Tools used in the Oslo Citizens' Observatory

In order to engage with citizens with the aim to empower them to participate in environmental governance, the project team created various tools and products that have been used in the different project locations. This chapter will provide a short information about the particular tools that have been used in the Oslo Citizens' Observatory. For more detailed information or information about further products, please visit www.citi-sense.eu or www.co.citi-sense.eu.

## 3.1 Static Sensor Platforms

A total of 64 static monitoring platforms have been deployed at different sites in the city of Oslo, including at 51 kindergartens. We have used AQMesh platforms v3.5 series (Fig 3.1) provided by Environmental Instruments Ltd. (www.aqmesh.com). AQMesh units are battery operated stationary platforms that in our case, measured four gaseous components (CO, NO, $NO_2$ and $O_3$) and particulate matter ($PM_{10}$ and $PM_{2.5}$). The AQMesh nodes measure also temperature, relative humidity and atmospheric pressure. Standard AQMesh nodes deliver one-hour averaged data but can be configured to deliver 15 min averaged data. An integrated GPRS modem allows data transfer to the AQMesh database server. The data can then be downloaded from a dedicated website.


*Figure 3.1 AQMesh static sensor platform deployed in the city of Oslo*

## 3.2 Personal Air Quality Monitoring Toolkit

This toolkit was provided by Ateknea (www.ateknea.com), and includes three different tools that allow to measure and visualize personal air quality in the users' immediate environment:

- Mobile sensor unit LEO (Little Environmental Observatory) (Fig 3.2)
- Android app (ExpoApp) that connects to the sensor unit, reads and uploads data to a server (Fig 3.3)
- Computer application for sensor management (firmware upgrade).


*Figure 3.2: Mobile sensor unit LEO*

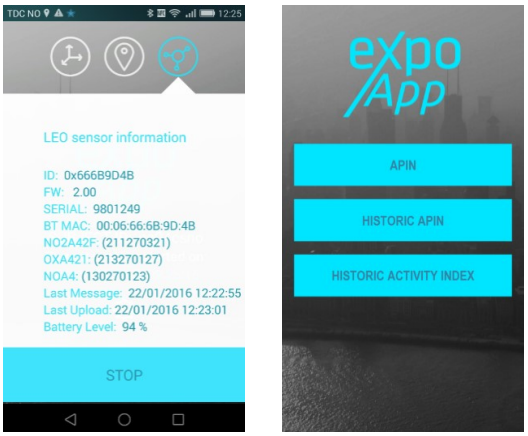


*Figure 3.3: Android app ExpoApp*

The LEO is a portable sensor pack, measuring NO, $NO_2$ and $O_3$. It also measures temperature and relative humidity. A proprietary algorithm is applied with the aim to correct the temperature and relative humidity interferences.

The ExpoApp is an Android application that communicates with the LEO. It reads and uploads data from the LEO and from the user's smartphone (i.e., location and physical activity). The connection to the LEO is established via Bluetooth. The app provides information about the status of the communication between smartphone and LEO and the smartphone and the data server. The user can visualize the measurement results using the ExpoApp application. The results are displayed in form of an Air Pollution Indication (APIN). The user can also consult the APIN value and the Activity Index over the last 24 hours. The time resolution is 1 minute.

The LEO sensor unit can be carried on the outside of a jacket, purse or backpack. Once the user's Android smartphone is paired with the LEO via Bluetooth, the ExpoApp can read and store data from the LEO. The measurements aim to give an indication of pollution levels and their changes, as the user moves through the city.

### 3.3 Data visualization portal

The CITI-SENSE team have developed a visualization portal where citizens can consult the data collected by the sensor nodes (static and mobile). The portal presents the last data collected, for the static AQMesh units that is the data collected during the last hour, and for the mobile LEO units the data collected during the last minute (Fig 3.4). In the case the node does not have updated data the measurements are presented as faded. The LEO users have also the possibility to log in to the portal to see their individual tracks. In this way, we do not display private data publicly.

The data from the sensors is presented as an Air Pollution Indication (APIN), with a 5 color scale: air pollution is very low, air pollution is low, air pollution is rather low, air pollution is rather high and air pollution is high. The APIN is also employed in the ExpoApp application to visualize the data from the LEO. The APIN is related to the Common Air Quality Index (CAQI)[5], but the two cannot directly be compared as the underlying air quality monitoring methods differ.

[5] https://www.airqualitynow.eu/about_indices_definition.php

The visualization portal also displays the air quality perception data collected using the CityAir app (see description in section 3.5), as well as an air quality map generated using the data from the static sensors. The portal presents several options regarding what information to display, for instance selection of type of data sets one want to visualize (e.g., static nodes, mobile nodes, air quality map).

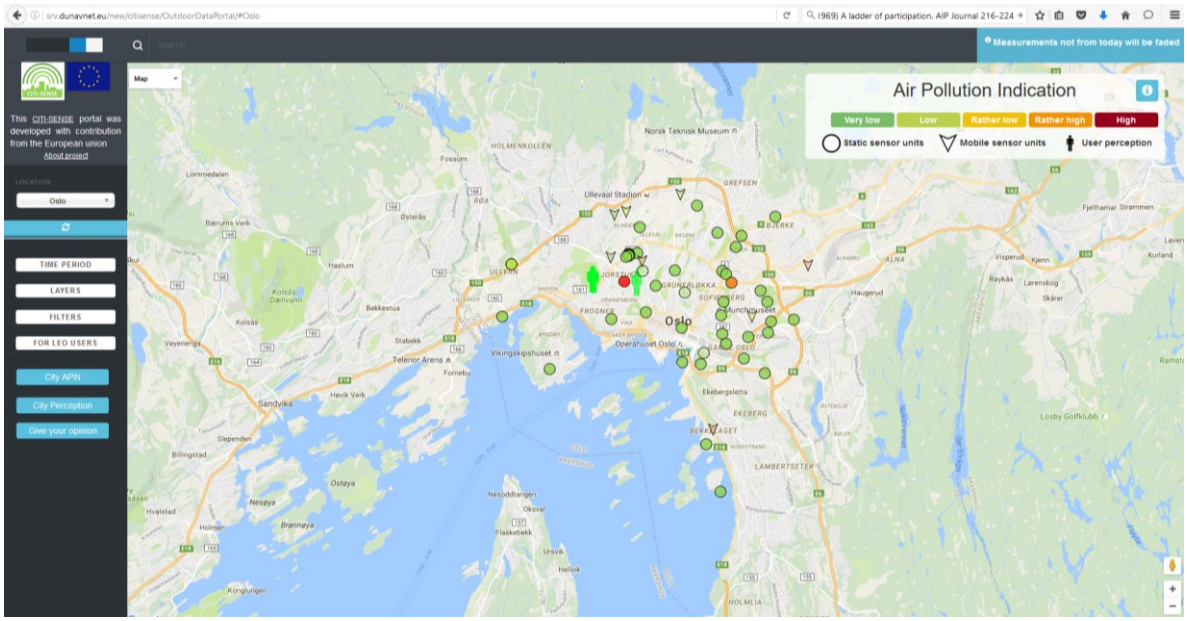


*Figure 3.4: Data Visualization Portal (http://srv.dunavnet.eu/new/citisense/OutdoorDataPortal/ )*

## 3.4 On-line Air Quality Perception Questionnaire

The CITI-SENSE On-line Air Quality Perception Questionnaire (Fig 3.5) is a tool for collecting and analyzing how the user perceives air quality issues. The tool can be used anywhere and modified according to the users' needs. For the CITI-SENSE project, the questionnaire includes the following three sections:

- Socio-demographic information.
- Specific questions on the participant's air quality perception.
- Feedback from the participant.

The collected data is available for visualization and analysis through the CITI-SENSE platform. The questionnaire can be accessed through computer, smartphone, and tablet. It is available in different languages. The full questionnaire in English can be consulted in the Appendix B.

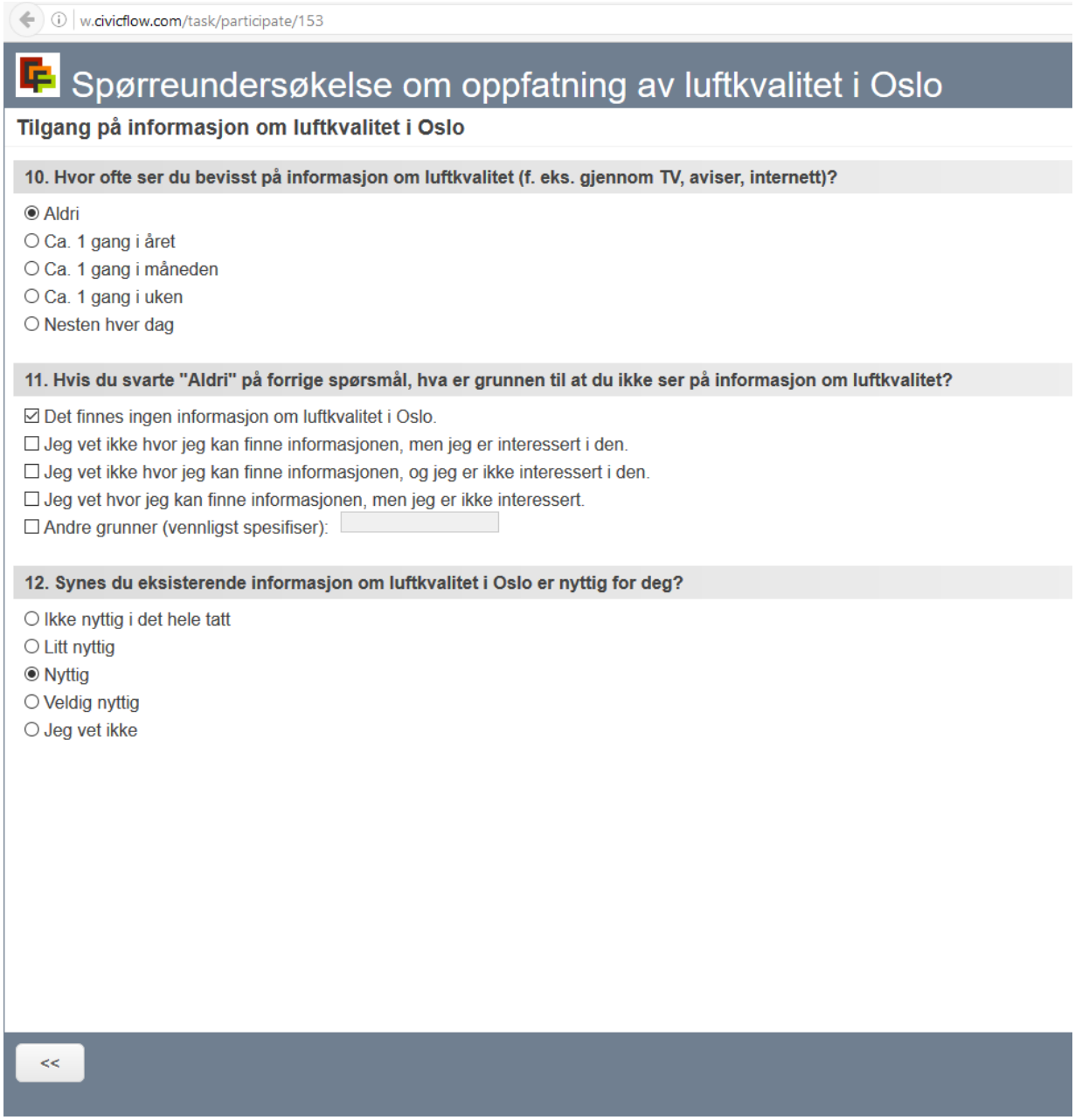


*Figure 3.5: CITI-SENSE On-line Air Quality Perception Questionnaire*

## 3.5 CityAir Smartphone App

CityAir is a smartphone application to provide information about peoples' personal perception of the outdoor air quality right where they are (Fig 3.6). The CityAir app was developed as a collaboration between CITI-SENSE and Citi-Sense-MOB[6] (Castell et al., 2015) projects. The app can be used in both Android and iPhone phones and was made available for free through Google Play and Apple Store. The links can be found in the Appendix A.

[6] www.citi-sense-mob.eu

When starting the app for the first time, the user is asked to provide socio-demographic information (i.e. gender, age and education level). The user can also choose not to insert that information. Air quality perception can be reported by using a coloured marker, based on a 4-point scale: green if the air quality is perceived as very good, yellow if the air quality is perceived as good, orange if the air quality is perceived as poor and red if air quality is perceived as very poor. If the user selects a yellow, orange or red marker, indicating that they perceive the air other than “very good”, a second screen will appear where the user can select the perceived pollution source. The user can select among the following sources: traffic, industry, house heating, port/harbour, dust, smoke, strong odour, pollen, others and “I do not know”. We decided to include pollen because the presence of air pollution can increase allergy symptoms. The user can also leave a comment. The CityAir app allows the user to see what other users have reported. The user has also the possibility of sharing the perceptions on Facebook (Fig 3.6).

Every time a user leaves a marker or a comment, that information is stored together with the information on GPS location, date, gender, age and education level. The data is stored locally on the phone and then uploaded and stored in the cloud. In case the user does not have internet connection while reporting, the information will be uploaded to the server as soon as the phone has internet connection. There is no limitation on the number of times that a user can report. The CityAir app can be used in any part of the world.

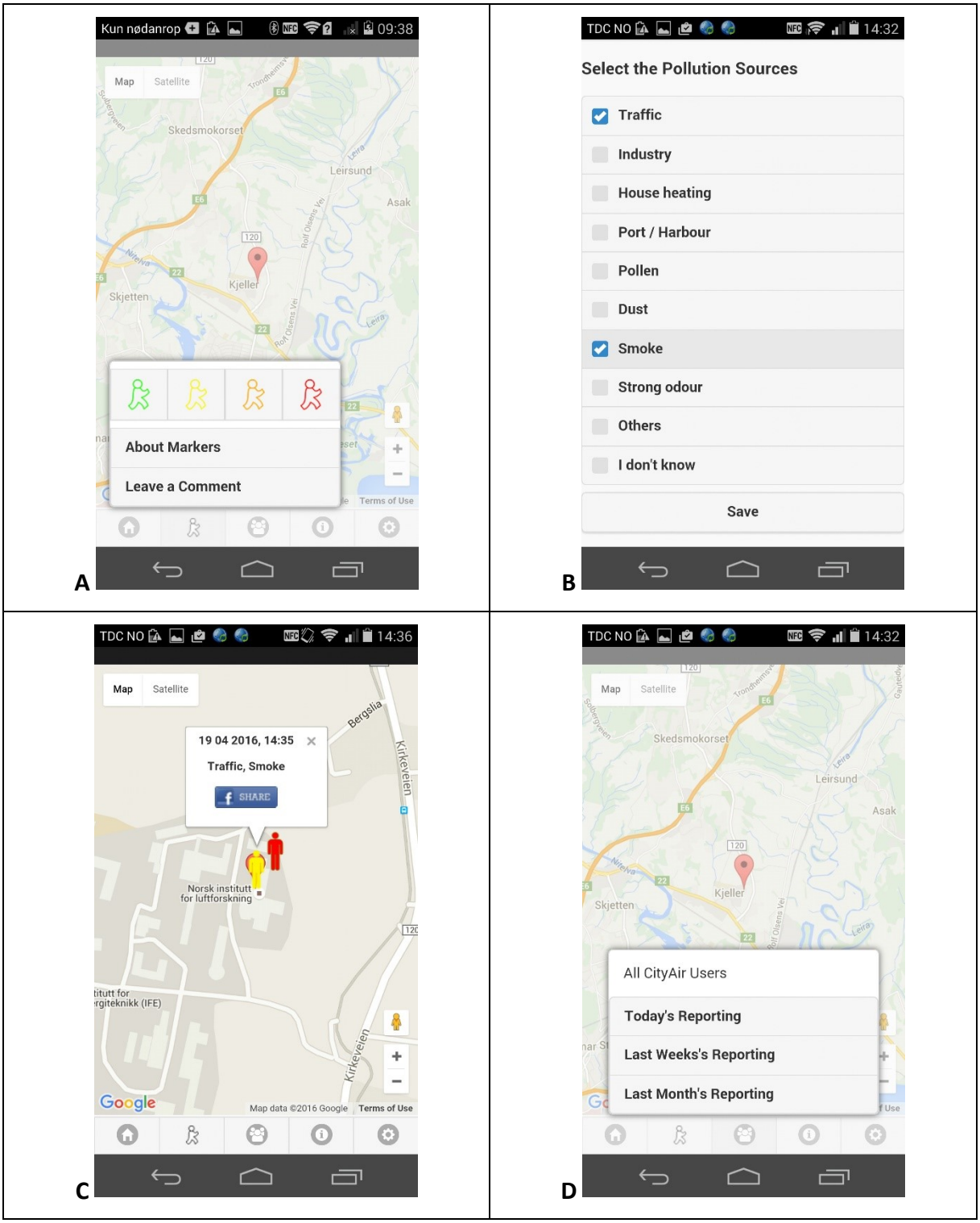


*Figure 3.6: Screen shots from the CityAir app. A: when clicking on the man button the user can choose between adding a colour marker according to his/her perception on air quality or leave a comment. In the option "About Markers" the user can read information about the meaning of each colour. B: When selecting an option different than green, i.e., air quality is other than "very good", the user will get a list of potential pollution sources. The user can then indicate the ones he/she thinks are causing reduced air quality. C: After reporting, the user can see his/her marker on the screen and can share it on his/her Facebook page. D: When clicking on the button with several people, the user can see what other users have reported today, last week or last month.*

# 4 Results from air quality monitoring using low-cost air quality sensors

## 4.1 Static Sensor Platforms and Data Visualization Portal

In Oslo, 64 static sensor platforms have been deployed to collect air quality data, 51 platforms have been deployed in the playground of Oslo kindergartens to provide near real-time data of the immediate environment there, and 13 units have been deployed in different streets in the city. Figure 4.1 shows the deployment of the static sensor platform. The sensor platform is placed outdoors at around 2.5 – 3 meters height.

*Figure 4.1: Sensor deployment in two kindergartens in Oslo.*

The sensor platforms were deployed in two periods. During the first period, in December 2015, 24 units were deployed in Oslo, 17 of them in kindergartens. During the second period, August 2016, we increased the number of monitoring points using 40 new units. During the second period we involved 34 new kindergartens in the air quality monitoring. Figure 4.2 shows the location of the static platforms in Oslo.

Before the sensor platforms were deployed in the city, they were co-located in one of the air quality monitoring stations in Oslo. The goal of the co-location was to test the performance of the sensor platform, and correct possible biases by applying a field calibration. The results of the co-location showed that the platforms provide measurements with accuracy much lower than required for regulatory purposes, but they can provide relative and aggregated information about the observed air quality (Castell et al., 2017). We found that some of the sensor types (NO and $PM_{10}$) can provide coarse information: air pollution is low, medium or high. However, other sensor types ($NO_2$, $O_3$, $PM_{2.5}$) have very high uncertainty even to provide coarse information on air quality.

It is important to note, that at the current stage of sensor development the data collected from the sensors platforms can not be used to draw conclusions about the air quality in the kindergartens.

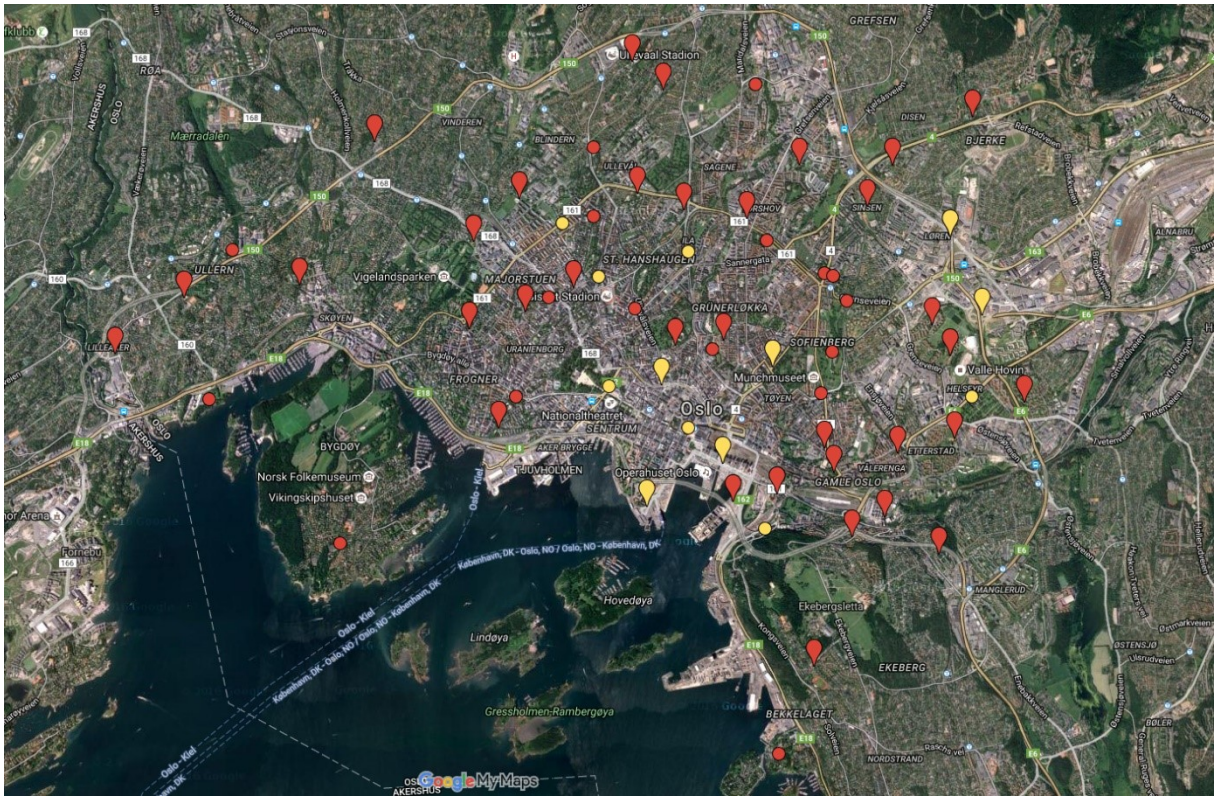


*Figure 4.2: Location of the static sensor platforms in Oslo. In red the kindergartens and in yellow the street locations. The circle represents the sensors deployed in the first stage (December 2015) and the tear the sensors deployed during the second stage (August 2016).*

The data from the static sensor platforms are being visualized in the Data visualization portal (see chapter 3.3). The data is presented by using an Air Pollution Indication (APIN) based on a 5 color scale. The link was provided to the participating kindergartens so the personnel and parents could see the collected data. They were informed that the data was not quality controlled (i.e., might have biases and errors associated) and that they are used only for research (i.e., it cannot be used to extract conclusions about the air quality at the kindergarten). Figure 4.3 shows an example of the data that could be accessed through the Visualization Portal.

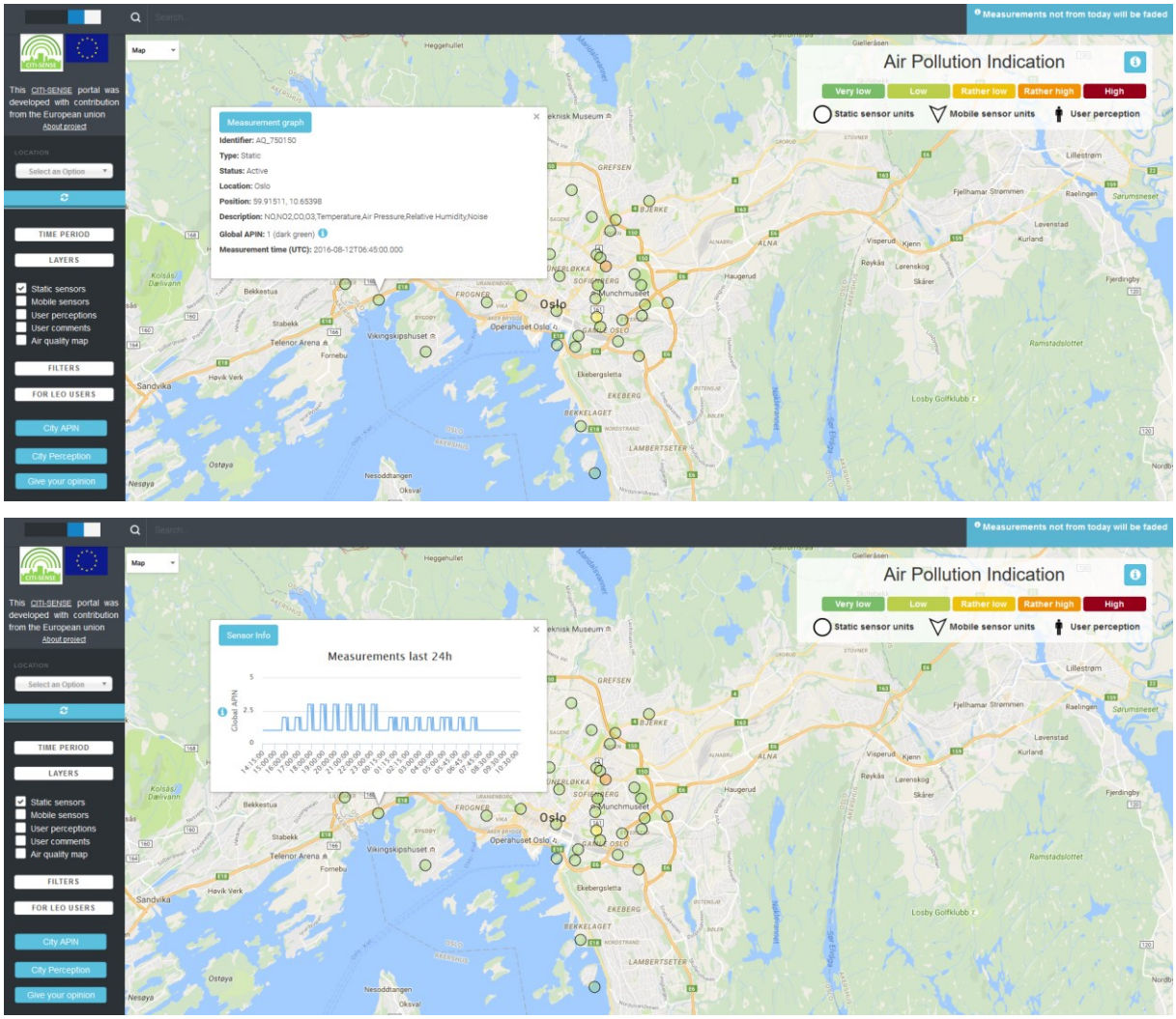


*Figure 4.3: Visualization of the APIN from the static sensors located in the city of Oslo. When clicking on the units, the user can see information about the sensor (top) or the measurements collected during the last 24 hours (bottom).*

The data collected by the static sensor platforms have been used to create an air quality map for the city of Oslo (Schneider et al., 2017). The map fuses the data from the sensors with the data from NILU's air quality model EPISODE (Slørdal et al., 2003). The main advantage is that this map can provide air quality information even in those places where we do not have any sensor platform. Figure 4.4 shows an example of the generated $NO_2$ map for 06.01.2016. The map shows that air pollution is higher along the main roads and during the times when there is more traffic. By combining the data of the sensor platforms with the air quality model we were able to visualize air quality patterns (Castell et al., 2017, 2018). However, more research is needed before this type of data can be employed in an operational mode (i.e., provide real-time maps).

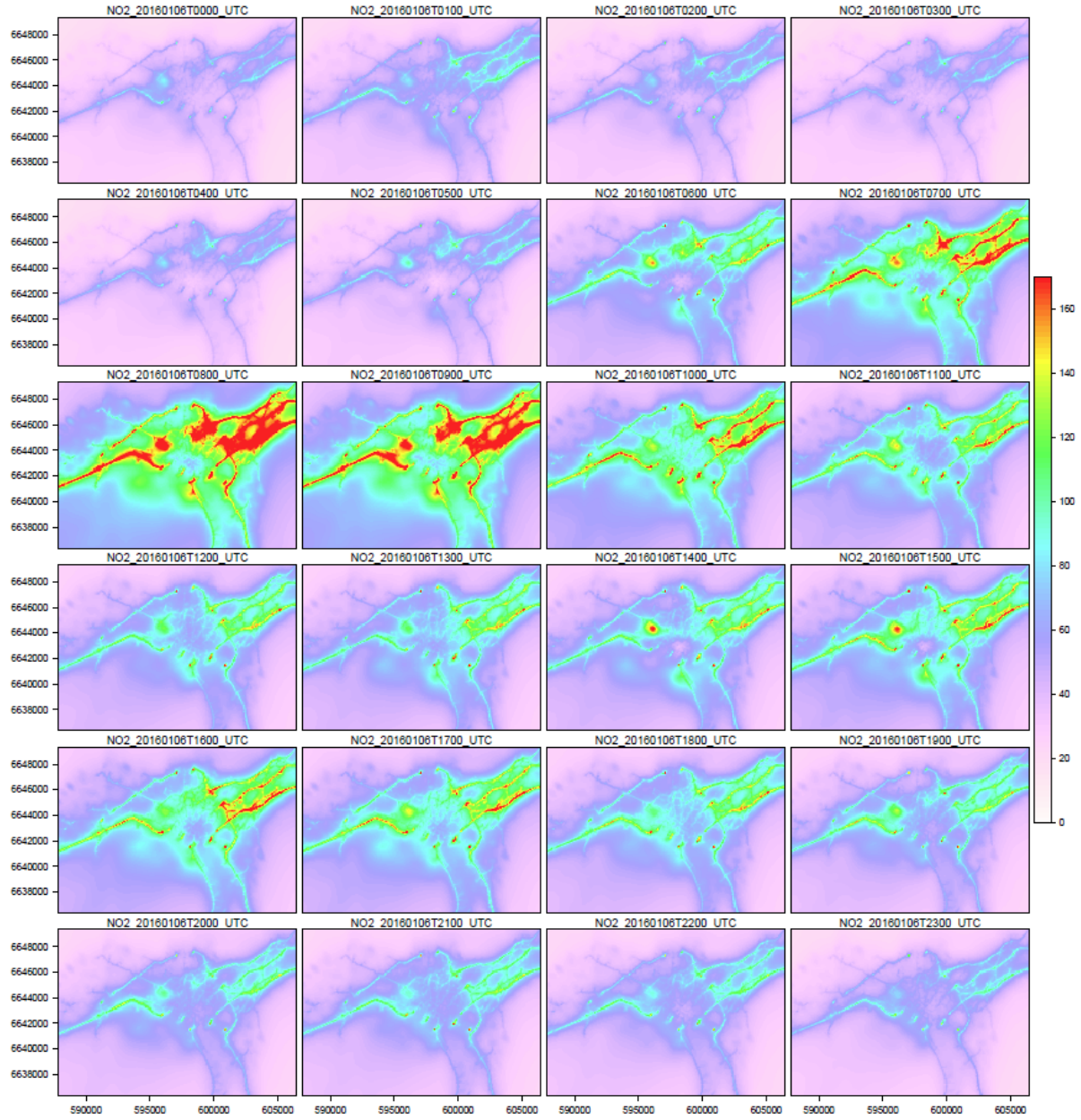


*Figure 4.4: Air quality $NO_2$ map for the city of Oslo created by combining the data from the static sensors and the annual average $NO_2$ concentrations from an air quality model. The results are for 06 January 2016 from 00:00 to 23:00. The map shows $NO_2$ concentrations in $\mu g/m^3$. In the Visualization Portal, the map only displays the 5 color scale of the APIN.*

## 4.2 Personal Air Monitoring Toolkit

The first version of the personal air monitoring toolkit was tested by the parking guards (bypatruljen). Their input was used to design the second prototype that was employed by volunteers in a later stage in the project.

After the information campaigns (e.g., participation in events, publication in social media platforms, distributions of leaflets) we received requests from more than 40 volunteers to carry the Personal Air Monitoring Toolkit and test it in Oslo. Finally, 32 volunteers participated in the campaign that took place between 15.04. and 02.06.2016. Every week, we equipped a group of 5-7 volunteers with LEO platforms and an Android phone with the ExpoApp pre-

installed. They tested the equipment for one work week and returned the toolkit afterwards to be used by the next volunteers. Figure 4.5 shows a person carrying a sensor platform on the arm while cycling in the city.

*Figure 4.5: Example of a person carrying a LEO sensor platform on their arm.*

During the 9 weeks of our campaign, we collected air quality data in a total of 26.800 points in Oslo. The temporal resolution of the LEO is 1 minute, allowing to track air pollution while the persons are moving in the city. Figure 4.6 shows datasets collected by two of the volunteers. The LEO platforms suffered from several problems when connecting with the ExpoApp, so that even if the volunteers were carrying the platform the data was not always successfully collected.

Similar to the results from the AQMesh sensor platforms, the readings from the LEO sensor platform need to be post-processed before conclusions on personal exposure can be drawn. The technology is still at its infancy and more research is required to allow this type of technology to be employed by citizens.

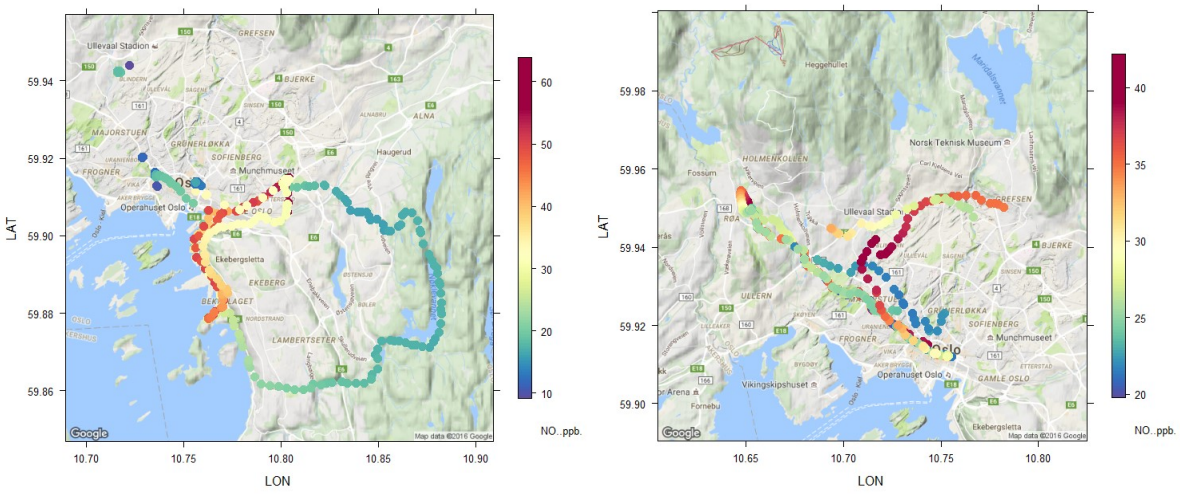


*Figure 4.6: Example of datasets of NO concentrations collected by two of the volunteers participating in the monitoring campaign in Oslo.*

# 5 Results on perception of air quality

## 5.1 On-line Air Quality Perception Questionnaire

The questionnaire targeted the adult population living, working or studying in the city of Oslo. The dissemination efforts were conducted coinciding with already existing events in the city, mainly targeting an audience that has already an interest in environmental issues. However, the use of social media and leaflets distributed in the city opened the project activities also to a wider audience.

The questionnaire was implemented in an on-line platform (CivicFlow) and was accessible using a web browser or a smart phone. No paper questionnaires were employed. In Oslo, the questionnaire was publicly accessible from September 2015 to June 2016. However, the main dissemination efforts were conducted during the end of September and beginning of October 2015.

With regard to the engagement process, the questionnaire has been disseminated and promoted through the following activities:

1. Participation in the "European mobility week" with a stand in three events: forum "Towards zero cars in Oslo" organized by a research institute; cinema event "Bikes versus cars" organized by the cyclist association; and the conference "Cycling in Oslo" organized by the Oslo municipality. It reached about 150 people.
2. Participation in a scientific breakfast seminar in the research campus in Oslo introducing the CITI-SENSE project, with 70 attendees.
3. Promotion of the questionnaire using a mailing list with 75 receivers to research institutes, NGOs and administrations asking to answer the survey and promote it among their contacts.
4. Distribution of leaflets by post to 21 public libraries in Oslo.
5. Distribution of leaflets in 3 schools and 17 kindergartens in Oslo.
6. Promotion of the survey in social media (twitter, web pages and facebook).
7. Link to the survey on the CITI-SENSE web site.

The questionnaire was available in Norwegian and in English. We employed back-translation, ensuring that the questions in different languages are equivalent.

By the end of the campaign, we had obtained questionnaires from 332 participants (290 in Norwegian and 42 in English). Most of the answers were obtained during September and October 2015, coinciding with the active dissemination campaigns.

The questionnaire had 20 questions, 3 of them optional additional questions at the end of the survey. The first 4 questions were socio-demographic questions (gender, age, level of education and occupation), the following 8 questions focused on the general perception of air quality, interest in air quality information and health awareness. The views on air quality related empowerment were evaluated through 4 questions on who has the power to improve air quality and how citizen should be involved. Finally, the participants were asked if they wanted to answer 3 more questions on how they would like to be informed about air quality.

The survey had a mix of single-choice close-ended questions, following a Likert-type scale, multiple-choice with an open-ended option and open-ended questions. A total of 9 of the questions were open-ended or had an open-ended option.

In the preliminary analysis, the percentage in each category of the closed-ended responses was analyzed without differentiating by gender, age or education level. The answers to the

open-ended questions were coded, classifying the comments in categories in order to identify the number of comments and remarks for each category of the answers.

In Oslo, the ratio of male to female respondents was 50%, and the respondents were in the age range between 31 and 50. Most of the respondents had completed higher education (85%), and 11% have completed a doctorate degree or higher. About 90% of the respondents live and/or work in Oslo.

### *5.1.1 Results*

The respondents show a high interest in air quality, with only 16% slightly interested or not interested at all in air quality (Fig 5.1). The perception of air quality in Oslo is very polarized, with 50% describing it as quite poor or very poor and 44% as quite good and very good (Fig 5.2). When analysing the reasons of the respondents for choosing that option, 255 of the comments are linked to a negative air quality perception, referring to the meteorology influence in winter time, the impact of traffic, and the specific situation in some places as for instance the city centre and along the highways. Ninety-one of the comments referred to a positive air quality perception (e.g. “good air quality where I live, work or go”) and the impression that Oslo air quality is better compared to other cities.

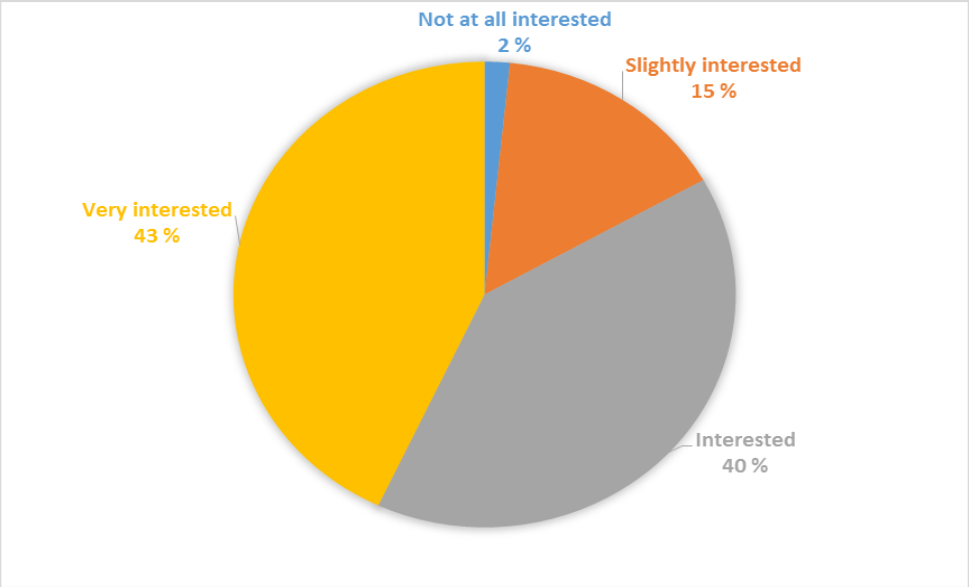


*Figure 5.1: Results from the Oslo questionnaire on the extent that people are interested in air quality.*

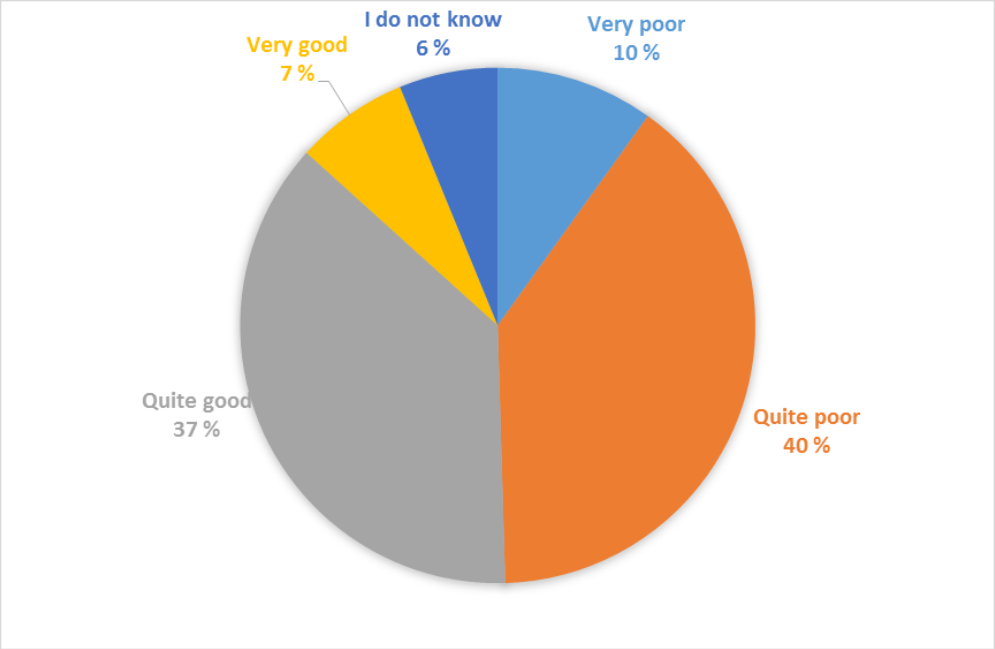


*Figure 5.: Results from the Oslo questionnaire on how people describe the air quality in the city.*

Most of the respondents (95%) answered that air quality in Oslo affects their health, and 32% of this group replied that air quality affects their health a lot (Fig 5.4). Despite that fact, 43% of the respondents do not consider air quality at all or only very little when moving around in the city. Only 24% of the respondents replied that they consider air quality a lot when moving in the city (Fig 5.5). From the questionnaire it is not possible to deduct if not considering air quality while moving in the city is caused by a lack of options (e.g., impossibility to change the commuting route) or a personal decision.

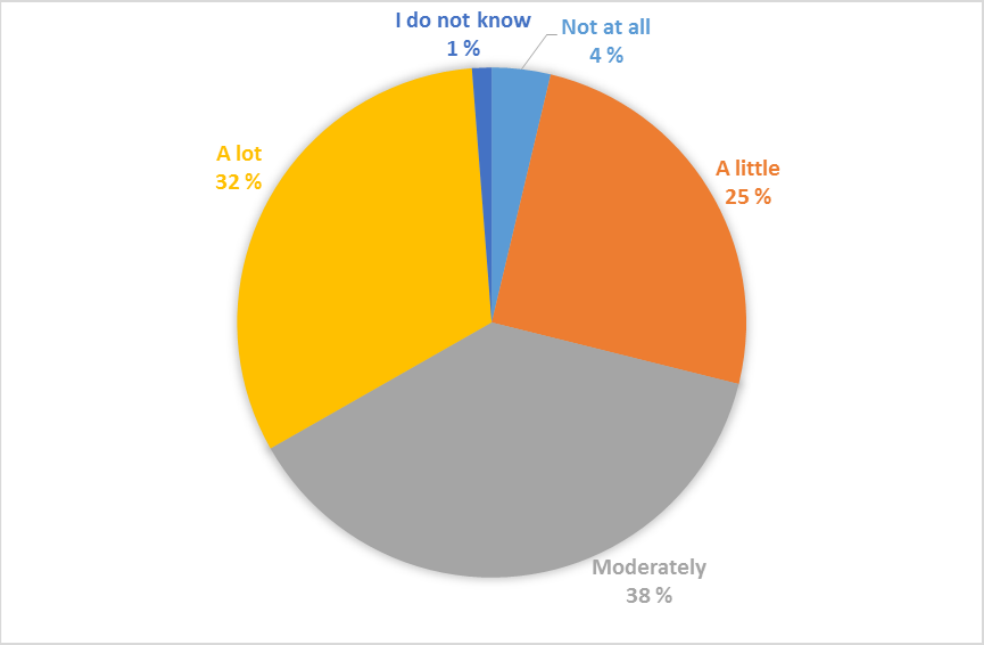


*Figure 5.4: Results from the Oslo questionnaire on the extent that people think air quality in Oslo affects their health.*

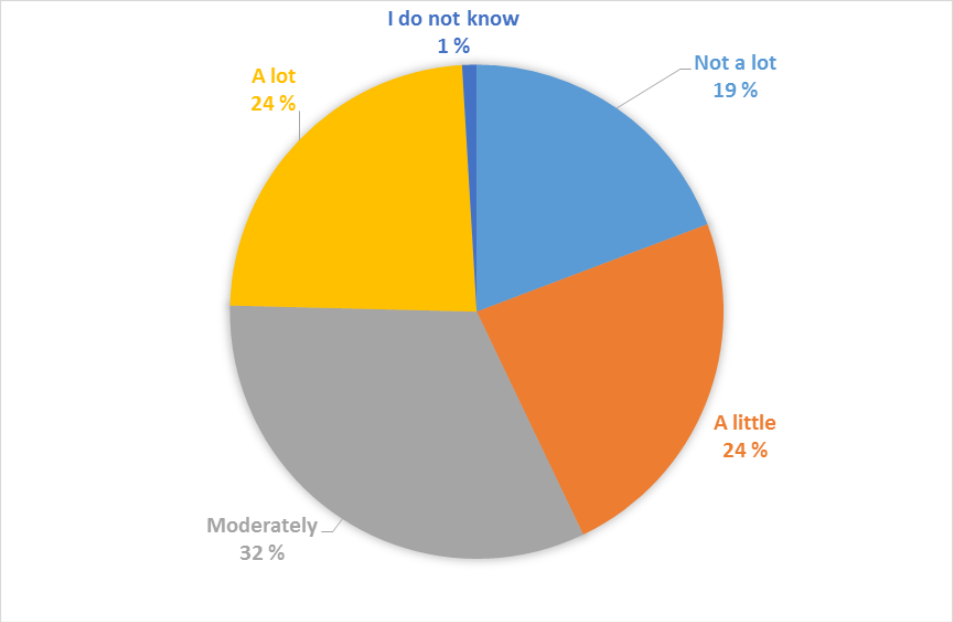


*Figure 5.5: Results from the Oslo questionnaire on the extent that people consider air quality when moving in the city.*

Even though most of the respondents showed high interest in air quality, only 25% admitted to check the air quality information regularly (once a week or more), and 47% declared that they look at air quality information only once a year or never (Fig 5.6). When asked for the reason, 58% replied that they do not know where to find the information but they are interested in it, and 26% replied that they are actually not interested in that type of information. Four of the 12 comments referred to the inability to act upon the information: "I don't know what to do with the information; I live where I live and I have to go where I have to go".

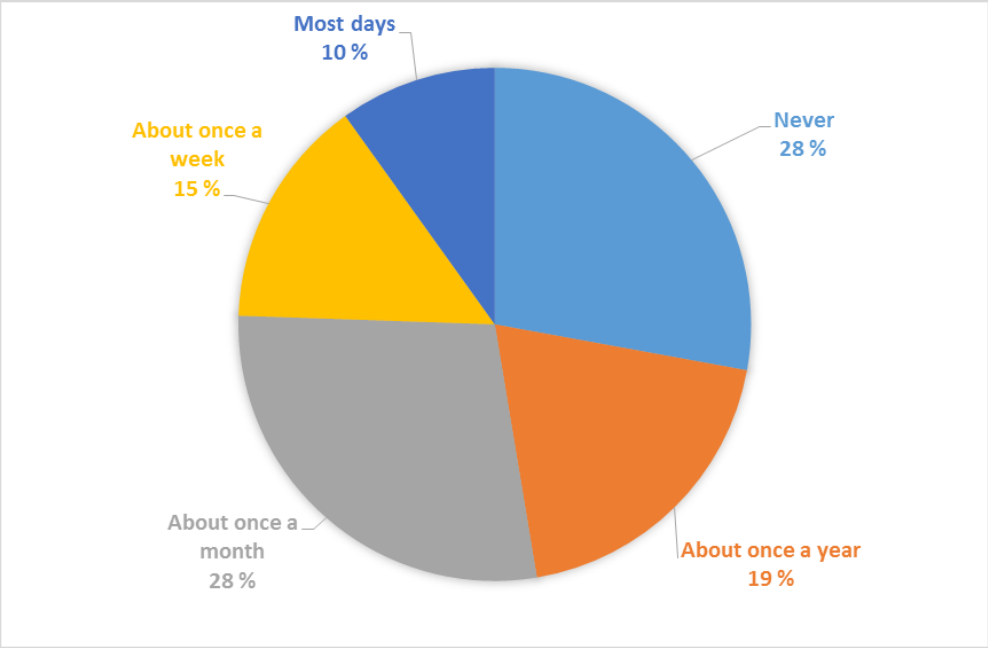


*Figure 5.6: Results from the Oslo questionnaire on the extent that people consult air quality information.*

The participants were also asked if the available information on air quality in Oslo was useful to them (Fig 5.7). Only 18% declared that it is very useful, most of the participants declared that it is slightly or moderately useful, 26% and 34%, respectively. In the comments about air quality in Oslo, air quality information was mentioned most often, with remarks on the necessity to facilitate the understanding of the information: “The information about air pollution is very technical and difficult to understand”, and its accessibility: “more information on the local newspaper”, “monitoring around schools and kindergartens”, “boards along the road and bike paths”.

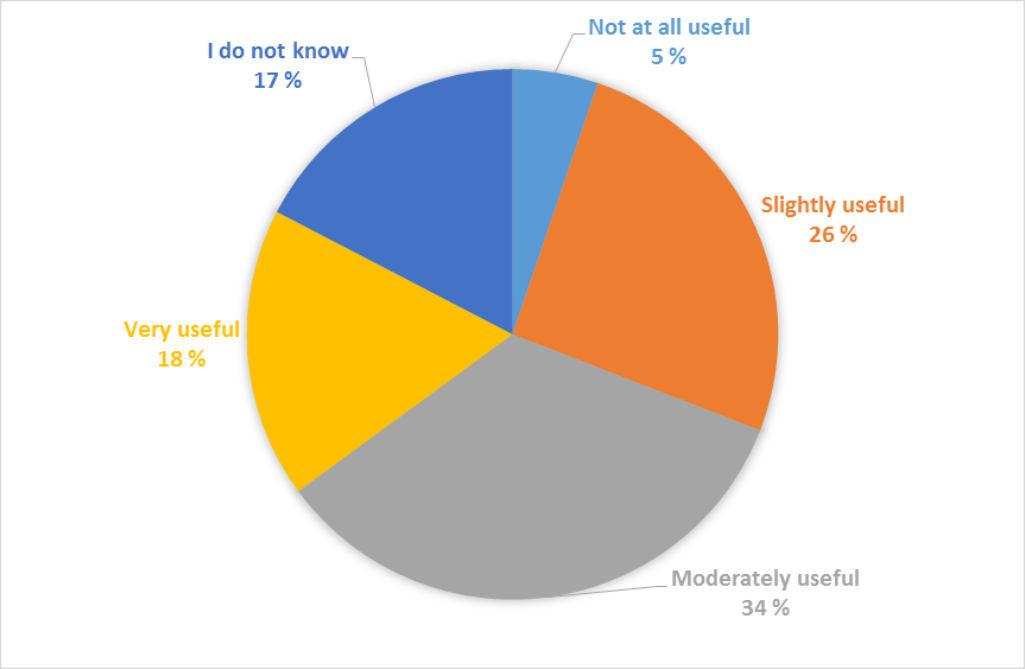


*Figure 5.7: Results from the Oslo questionnaire on the usefulness of air quality information*

Municipality, regional and central governmental bodies were identified as the group that can contribute most to improving air quality in Oslo, with 49% responses. Citizens (commuters and people who spend most of their time in the city) are the second group, selected by 24% of the participants. Industry and commerce is the third group with 20% responses. Only 4% of the respondents replied that scientists are one of the 3 groups that can contribute most to improve air quality.

Regarding how each of the identified groups can contribute, 397 comments referred to authorities, 127 comments to actions by citizens and 33 to industry and commerce. For the authorities most of the comments referred to transport (72%) and legislation and regulations (22%). Examples are traffic and vehicles restrictions, promotion and extension of public transport and creation or improvement of infrastructure (e.g., tunnels, cycling paths). For citizens, most of the comments referred to use of public transport (32%) and cycling and walking options (18%). For industry and commerce, most of the comments referred to their responsibilities (84%) and pointed out the specific contribution from the Oslo harbour to air pollution (16%).

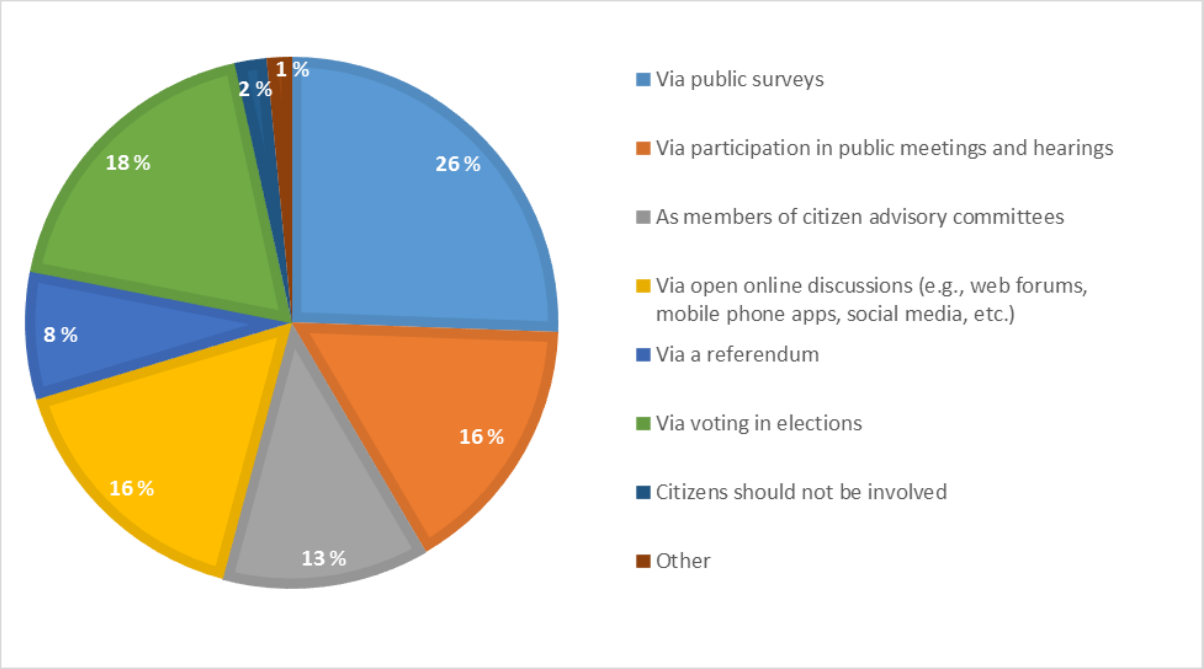


*Figure 5.8: Results from the Oslo questionnaire on how citizens should be involved in policy-making.*

When asked about citizen involvement in policy-making, 98% of the respondents agree that citizens should be involved (Fig 5.8). Most of the participants (58%) identified public surveys, participation in public meetings and online discussions as a way to be involved. Voting in elections and referendums was selected by 26% of the participants. A total of 13% of the participants choose participation as members of citizen advisory committees.

Even though only 2% declared that citizens should not be involved in policy-making, only 16% of the respondents chose to personally get involved in policy-making when asked about the steps they would personally take to help improve air quality in Oslo. Most of the respondents chose the use of more environmentally friendly transport options (43%) and systems at home (30%). Only 4% of the respondents replied that they do not have the capacity to take any steps to improve air quality.

***Extra section on visualization of air quality information in an mobile app***

Eighty-one percent of the participants replied to the three additional questions on how they would like to receive air quality information in a mobile app.

The top-five formats to receive air quality information were: mobile phone application (27%), website (21%), social media (16%), information panels (13%) and radio (9%).

The respondents were asked to rate on a scale of 1 to 5 (not a priority, low priority, medium priority, high priority and essential) the following options:

- ✓ Air quality in your immediate vicinity (i.e., where you are)
- ✓ Numeric information on pollutant concentrations in the air
- ✓ An air quality index indicating if the air quality is poor or good
- ✓ Ability to report what you think the air quality is like
- ✓ Information on past air quality
- ✓ Information on current air quality
- ✓ Information on forecasted air quality
- ✓ Information on what to do to protect your health

- ✓ Notifications in case of increased air pollution
- ✓ Possibility to see the air quality levels in the routes you move around the city
- ✓ Possibility to select cleaner routes to move in the city

In Fig 5.9, we see the ranking of the different options to receive information about air quality. The possibilities of having air quality in the vicinity and notifications in case of increased air pollution are ranked as high priority and essential. The results also show that having an air quality index is more essential for the participants than having information on the pollution concentration. In a mobile app, having information on current air quality is the most essential, followed by information of forecasted air quality. Other important features are the possibility to see the air quality in the routes people use to move in the city or the possibility to select cleaner alternative routes. The ability to report the opinion on air quality and to see what other users have reported has a medium-low priority.

Some of the comments referred to the need to contextualize information (i.e., what are the consequences for me, what are the causes of air pollution), give advices (e.g., is it better to take the car than the bike), combine with other information (e.g., diesel free day, meteorological information, park and ride places, implemented measures to mitigate air pollution) and create a map feature (e.g., possibility to select areas in a map).

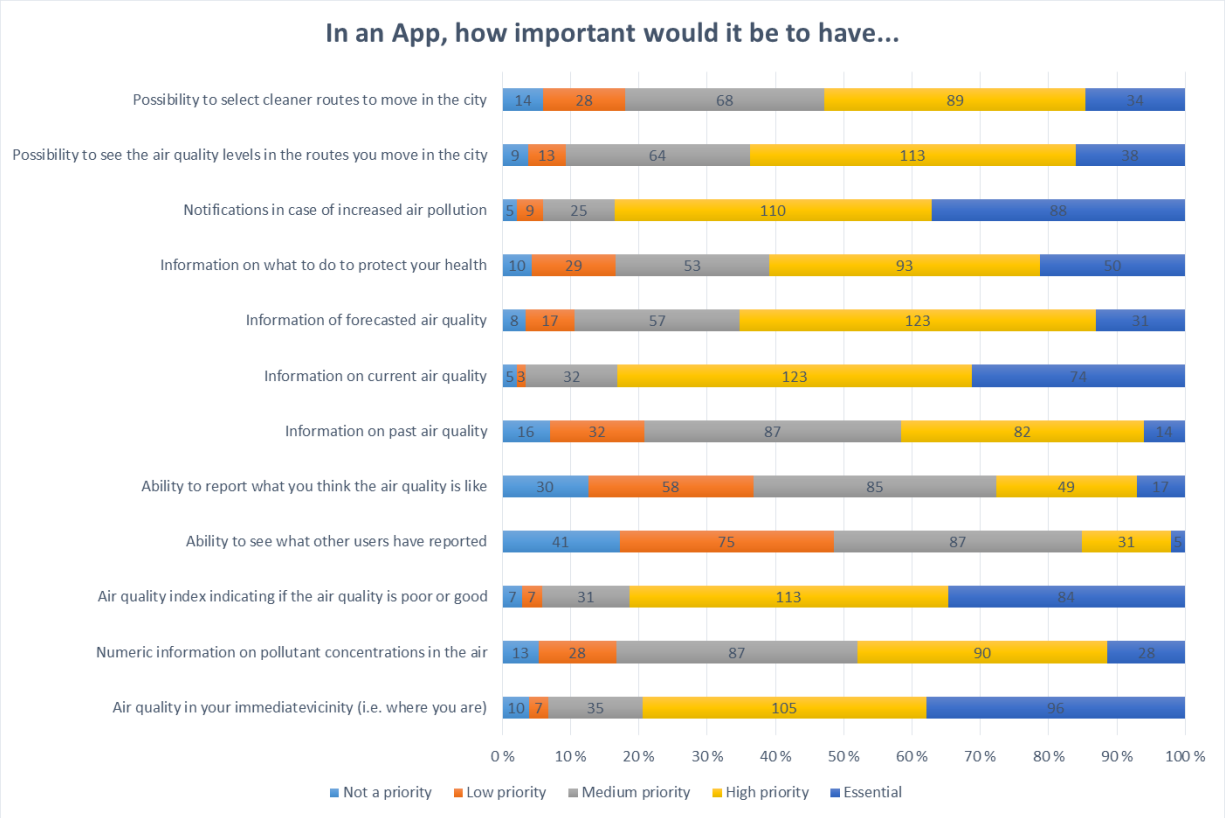


*Figure 5.9: Prioritization of what information to display in a mobile phone application on air quality.*

## 5.2 CityAir Smartphone App

The CityAir app targeted the adult population living, working or studying in the city of Oslo. The necessity of having a smartphone might have limited the number of people that are able to use it, even though in Norway, the percentage of people who used a smartphone in 2015

was 79%[7]. However, some people reported that the app could not be installed in older smartphones or was not working properly. Thus, this results in a limitation in the number of people that could install and use the app.

The CityAir app has been disseminated and promoted through the following activities:

1. Participation in the "European mobility week" with a stand in three events: forum "Towards zero cars in Oslo" organized by a research institute; cinema event "Bikes versus cars" organized by the cyclist association; and the conference "Cycling in Oslo" organized by the Oslo municipality. It reached about 150 people.
2. Participation in a scientific breakfast seminar at the research campus in Oslo introducing the CITI-SENSE project, with 70 attendees.
3. Distribution of leaflets by post to 21 public libraries in Oslo.
4. Distribution of leaflets to 3 schools and 17 kindergartens in Oslo.
5. Promotion of the CityAir app in social media (twitter, web pages and facebook).
6. Link to the CityAir app on the CITI-SENSE web site.
7. Promotion among 40 volunteers that were participating in a campaign carrying an air pollution sensor for one week. The volunteers were provided with a mobile phone with the CityAir app pre-installed and were asked to use it while carrying the sensor.
8. A dedicated campaign of 4 days (Friday to Monday) when the use of the app was actively promoted through the social media accounts of the project (Facebook and Twitter), two research institutes (NILU and SINTEF) and one NGO (NAAF Norwegian Asthma and Allergy Association).

During the period between September 2015 and June 2016, people in Oslo could use the CityAir app to report their perception on air quality in their direct surroundings. That information is linked to the location and the time the report is done. A total of 316 reports were collected, 304 colour makers and 12 open-ended comments. More than 60% of the reports were collected during April and May, coinciding with the promotion among volunteers and a dedicated CityAir campaign. The difficulty of compiling information outside dedicated campaigns has also been mentioned in other crowdsourcing and citizen science activities (Baruch et al., 2016).

### *5.2.1 Results*

The CityAir app had an even use distribution between men and women. The largest part of the users was between 31 and 50 years old (78%) and had a university degree or a PhD or equivalent title (92%). A total of 25% of the markers had no associated demographic information.

In Oslo, periods with higher pollution levels can occur in winter. During the winter months, we did not conduct any dedicated campaign to promote the use of the CityAir app. This resulted in a low participation in the months between November and February (21% of the markers). It was during the months of April and May that most of the reports were collected (63% of the markers), as a result of more intensive recruitment campaigns. During these months,

[7] http://www.statista.com/statistics/488355/smartphone-penetration-norway/

particulate matter levels can be high mainly as result of the dust resuspension from the use of studded tyres.

Considering the full period (15 September 2015 to 15 June 2016), the markers were distributed as follows: 53% very good air quality, 26% good air quality, 12% poor air quality and 9% very bad air quality. Traffic was pointed out by 50% of the participants as the main source, followed by dust (17%) and house heating (8%). In the months of April and June the perception of the air quality followed a similar distribution as for the full period, with 50% reporting the air quality as very good, 28% as good, 12% as bad, and 10% as very bad. However, the distribution of the main sources is different from the average distribution of the full period. Between April and June, traffic was reported as the main source (53%), followed by dust (19%) and pollen (8%).

The results show that the reported air quality perception was inconsistent with the air quality levels monitored in Oslo. For example, on days when air pollution was classified as moderate or high, more than 50% reported “air quality is very good”. We did not find a connection between user perception and daily average concentrations of particulate matter. Our results show that perception of air quality was unrelated to the real exposure.

We found a relationship between the awareness of air quality and the proximity to busy roads. The roads that have higher average traffic intensity are perceived as more polluted. The location and its surroundings are important in the perception of air pollution, and people are able to relate, to some extent, traffic to air pollution. However, air pollution, and especially particulate matter, can also have high concentrations in areas with low or no traffic. Contributions from other sources such as house heating and transport from other areas inside and outside the city are also important.

The fact that city dwellers are not intuitively able to distinguish between low and high particulate matter concentrations gives even more importance to the question on how to provide better information to the public so they can take actions to reduce their exposure.

Figure 5.10 shows the air quality perception reported between 15 September 2015 and 15 June 2016 in Oslo. The map shows that the reports were collected for the whole Oslo area and especially inside Ring 3. Figures 5.11 and 5.12 show the reports in two different areas in Oslo, in the centre inside Ring 1 and north of the centre and along Ring 2. The map shows how the perceptions of air quality can vary inside the same area. However, it is also possible to detect areas where most of the reports, even performed in different days and times, agree on the same classification of air quality. In that sense, the CityAir app can detect spots in the city that trigger different perceptions and help to form a clearer picture of how local context influences the perception.

The CityAir app can also be a tool to investigate the areas in the city that trigger certain collective responses, for instance areas where most users define “air quality is bad”. In general, mapping air quality perceptions can help to form a clearer picture of how local context influences the opinion. A better understanding of the perception of city users regarding air quality can help to achieve better environmental health standards in the city. For instance, it will allow the development of targeted outreach campaigns by local authorities and policy makers to protect the population from air pollution exposure. Recent studies found that behaviour change was predominantly motivated by perception of the environmental conditions and not by the advisory system (Semenza et al., 2008). Perception is a key factor influencing the public acceptance of environmental policy.

Understanding the role of air quality in the overall satisfaction with the environment opens new doors for citizen-centric spatial planning and development of urban spaces. Individuals' perception of environmental conditions can influence the "liveability" of a city. Cityair app can be used as a tool to give voice to the citizens about their concerns regarding air quality.

This study suffered some data limitations and should be considered an initial examination of the local air quality perception. Additional data and further research are needed to form a more complete understanding of the topic.

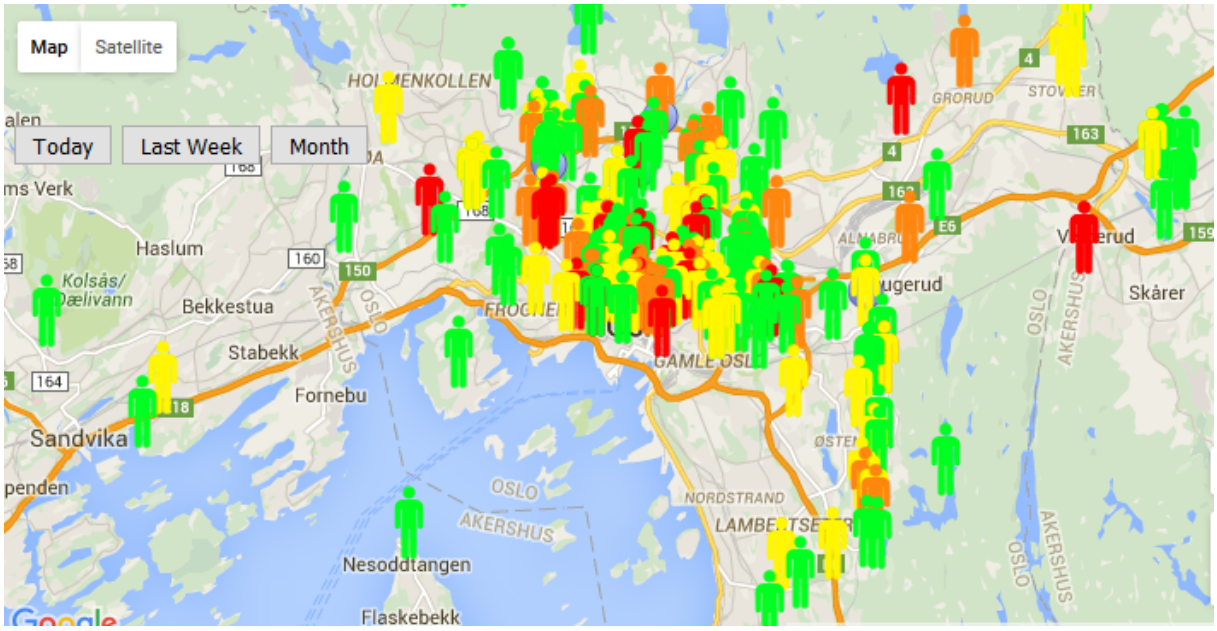


*Figure 5.10: Air quality perception reported during the period between 15 September 2015 and 15 June 2016 in Oslo.*

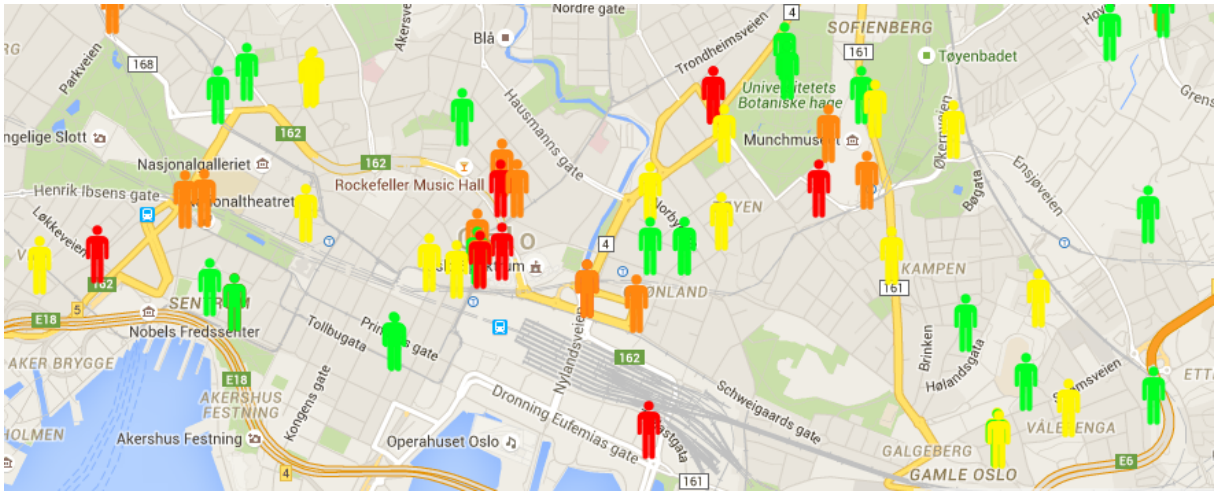


*Figure 5.11: Air quality perception reported during the period between 15 June 2015 and 15 September 2016 in the downtown area in Oslo.*

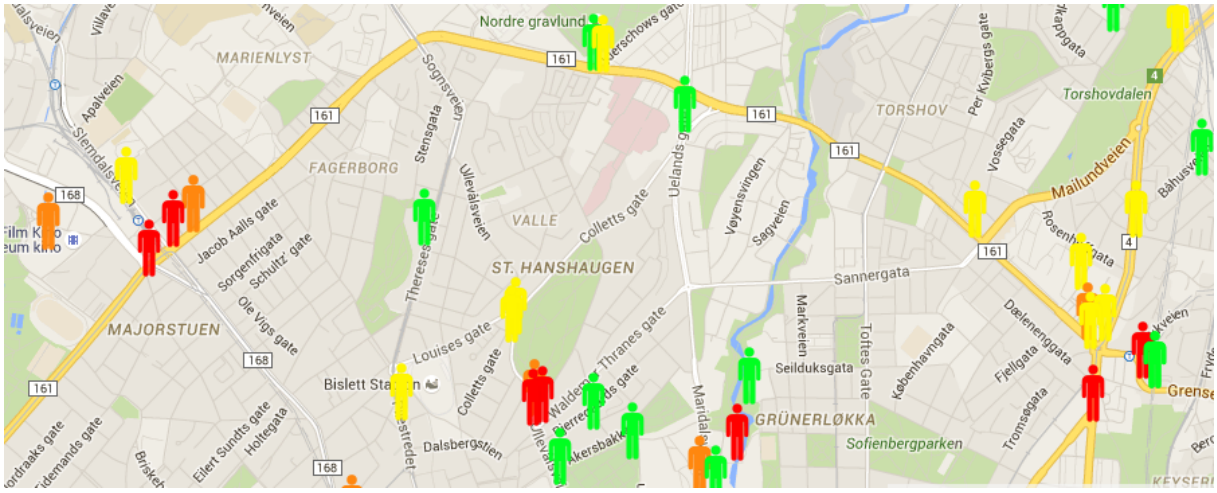


*Figure 5.12: Air quality perception reported during the period between 15 June 2015 and 15 September 2016 in the upper city centre and along the highway (Ring 2) that connects the East and West parts of Oslo.*

# 6 Results from User Evaluation

We have carried out different measures to obtain feedback from the users on the tools that have been used in the CITI-SENSE activities in Oslo. One tool was an online questionnaire on the usability of the products[8]. In Oslo, this has been used by 38 people, of whom 26 evaluated the LEO and 12 the CityAir app. Furthermore, a focus group has been held with volunteers of the LEO to receive more information about the users' experience with the tools. Another focus group has been held to evaluate the usability of the CityAir app and the Data Visualisation Portal. In an interview with Oslo Municipality representative, we heard about their view on the CityAir app and the On-line Air Quality Perception Questionnaire. An interview with employees at the Norwegian Asthma and Allergy Association (NAAF) has been held about their view on the CityAir app.

## 6.1 Static Sensor Platforms and Data Visualization Portal

The data from the static sensor platforms in both the kindergartens and other locations in town have been visualized through the data visualization portal. Volunteers carrying a LEO sensor could also see the routes they were taking with the LEOs in this web pages. In order to protect their identity, they had to log-in first. Although the volunteers that were carrying a LEO sensor received information about and the link to the data visualization web page, nobody used the online evaluation questionnaire to evaluate the web portal. Therefore, we have carried out a focus group "interview" with three volunteers to obtain their feedback on the product after a short demonstration.

The volunteers rated the web portal as rather useful. Data on air quality can be visualized and this could help for example parents of asthmatic children to plan medication, kindergartens to plan their activities or politicians to take actions. For this reason, additional health related information would be very much appreciated by the participants. And very important in this context is the communication of information. This has to be done in a way that is easy to understand for people without scientific background. However, such information web portal will need to be tested in practice before we can ensure its usefulness for sensitive groups. The focus group also underlined the importance of long-term measurements and their visualization. In addition, they see a potential to motivate people that so far have not been interested in air quality/air pollution because they now see the actual values and can relate them to the fact that they could be dangerous for their health or the health of their children. In that sense, it could also serve as educational tool and eventually become a tool for citizens to "perform" political press on the authorities.

Although the data visualization web page has been considered at quite useful in some respects, uncertainty of data would limit the actions the volunteers can undertake based on the air quality information they obtain from it. In addition, economic limitations would also

[8] Norwegian:
https://docs.google.com/forms/d/1u3uhAoHBi74pa2NxJ5KTA59DOIt7X4UucrQKotUPQYw/edit?usp=forms_home&ths=true

English:
https://docs.google.com/forms/d/1u3uhAoHBi74pa2NxJ5KTA59DOIt7X4UucrQKotUPQYw/edit?usp=forms_home&ths=true

prevent them from taking immediate actions, such as for example moving house to a less polluted area in town.

## 6.2 Personal Air Monitoring Toolkit

Thirty two volunteers have agreed to carry a LEO sensor for one week. They have been asked to fill in the Usability Evaluation for this tool, and 26 of them did.

11 men and 15 women evaluated the LEO of which 64% were between 28 and 41 years old. All of them lived or lived and worked in Oslo. More than 50% had a master degree. All of the participants were interested in the topic of air pollution.

Asked whether they would like to use the LEO more frequent, the majority of the volunteers declined (19% strongly disagreed, 35% disagreed; Fig 6.1). The reason was probably not its complexity since the majority (35%) of the volunteers replied to the question if they found the LEO unnecessary complex “neither/nor” (Fig 6.2). The majority of the respondents (42%) found the LEO was not easy to use (Fig 6.3). Nevertheless, the volunteers’ opinion about the need for technical assistance for using the LEO was twofold – 38% agreed and 38% disagreed (Fig 6.4).

The majority thought that the functionalities were not well-integrated (46%) (Figure 5.). On the question about inconsistency in the system, 27% of the respondents thought there was too much inconsistency, 15% disagreed and 35% decided for “neither/nor”. 19% did not know and 4% did not reply to the question at all (Figure 5.). This might indicate that this question was not well understood by the participants and they could not relate it to the LEO.

Fourty-six percent of the volunteers stated that they found it easy to learn how to use the LEO and the same percentage felt confident using the LEO (Fig 6.7 & 6.8). The majority stated that they did not have to learn a lot of things before using it (38%) (Fig 6.9) and 46% of the participating volunteers report that they have learned something useful by using the LEO (Fig 6.10).

The majority (54%) would rather not recommend it to their friends and family (Fig 6.11). A large majority (69%) would use the LEO in the future (Fig 6.12). Only 19% of the volunteers were satisfied with the LEO (vs 38% that were not satisfied and 38% who replied “neither/nor” (Fig 6.13). Almost 70% have not used the LEO very often (Fig 6.14).

Asked about the most useful aspect of the LEO, the volunteers reported most often awareness raising (“Nice to measure AQ on my way to work. Raises awareness about AQ in my close environment, not only in general”), learning about different AQ measurement products (“To learn more about opportunities and limitations of this tool”) and visualization of air pollution (“That you can see the AQ in those places where you move every day”) (33% each).

As most disappointing aspect the majority mentioned the technical difficulties (50%) (“The app got stuck – didn’t work in the beginning of the period, despite re-starting the mobile phone. Couldn’t use the equipment”), the lack of user friendliness (20%) (“The app could have been even more intuitive, the same applies for the whole tool”), and the fact that the data were not visible (15%) (“Difficult to see what I have sampled”). Thus, the category “Further comments” was relating to improving both technology and user friendliness (“Provide better developed and more user friendly tools to the general public”).

To conclude, the participants did not seem to be very satisfied with the LEO overall. Although the majority thought it was easy to learn how to use the LEO and they felt confident using it, the results showed that they have not used the LEO very often. The participants described the tool as unnecessarily complex, not user friendly, they would need the support of a technical person to use the LEO and not all functions were well integrated. Thus, they would not recommend the LEO to their families and friends. However, the participants also report that they have learned something useful by testing this tool.

In order to obtain more detailed information about the usefulness of the LEO, we have carried out a focus group interview with 3 persons. The participants agreed that it would be a useful tool once it was up and running properly.

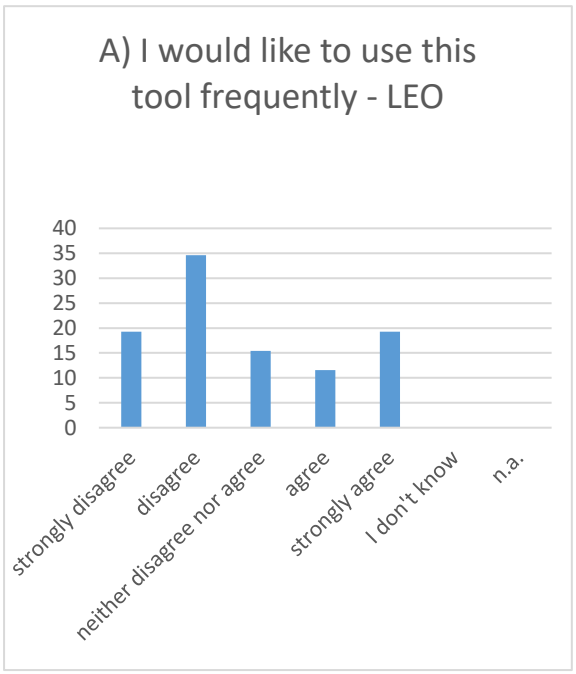


*Figure 6.1: More frequent use of LEO*

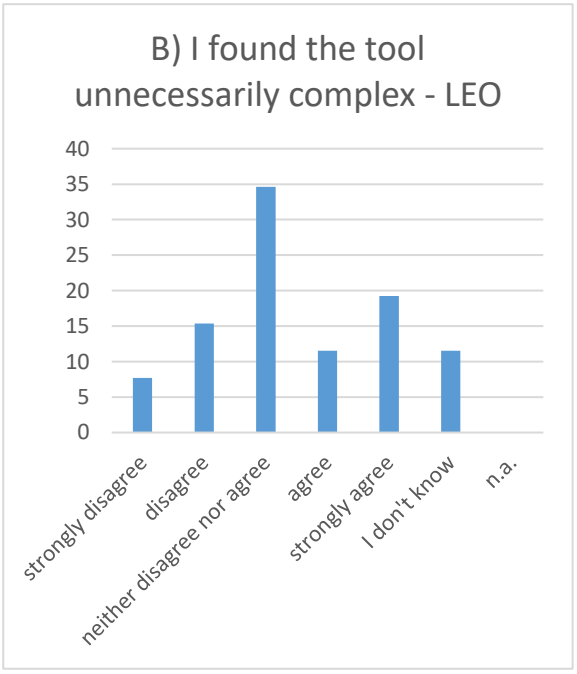


*Figure 6.2: Complexity of the LEO*

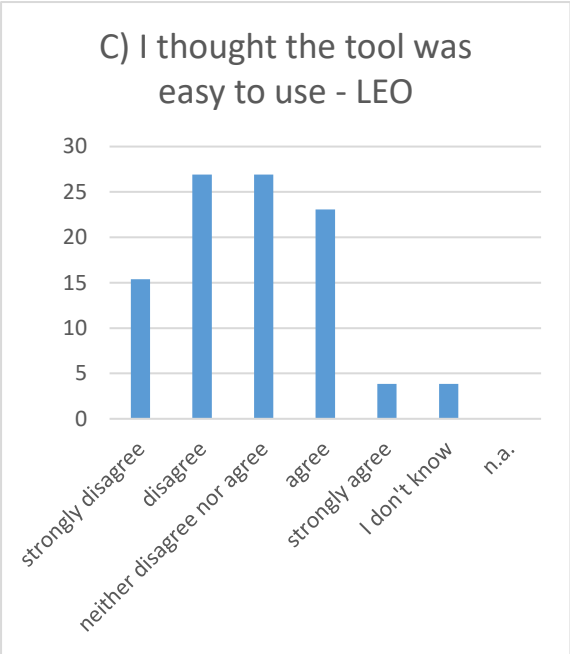


*Figure 6.3: Easiness of use*

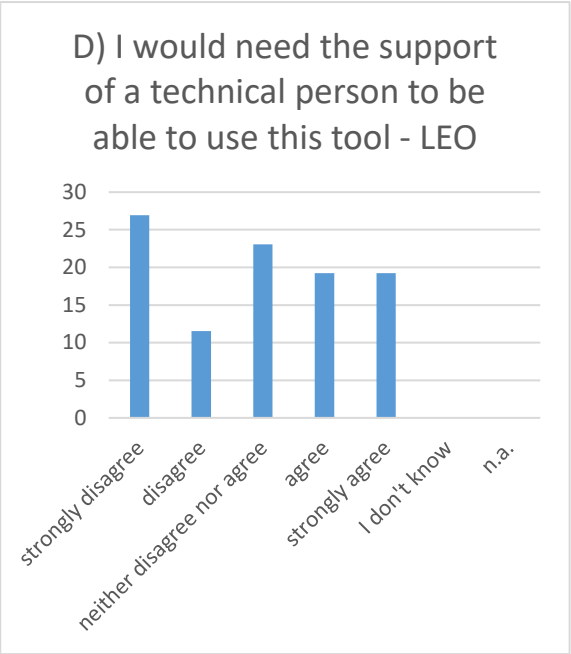


*Figure 6.4: Support of a technical person*

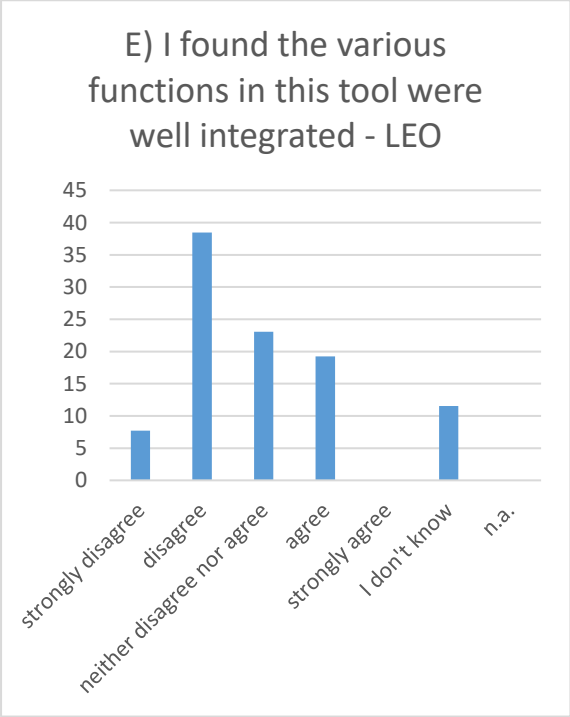


*Figure 6.5: Integration of various functions*

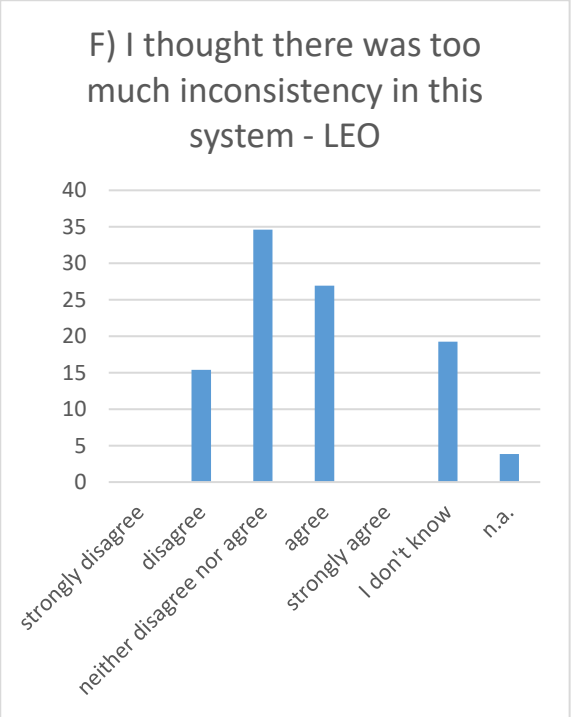


*Figure 6.6: Inconsistency within the LEO*

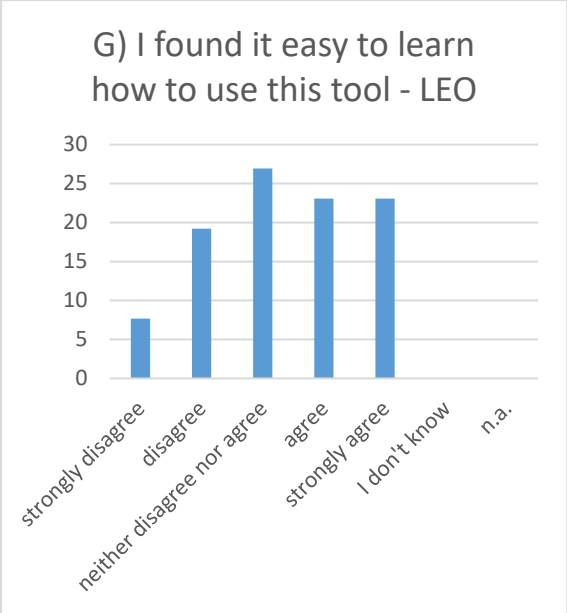


*Figure 6.7: Easiness to learn to use*

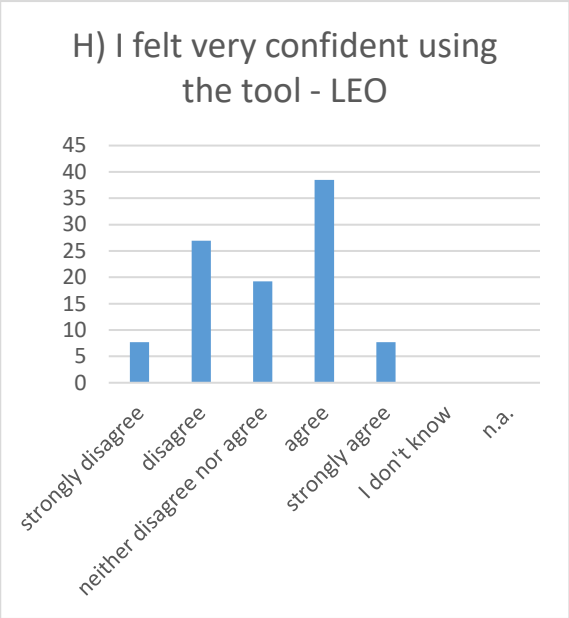


*Figure 6.8:Confidence in using the LEO*

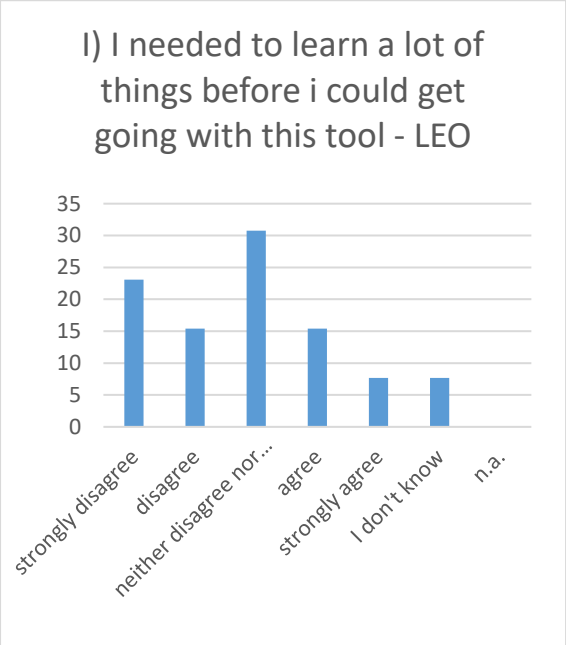


*Figure 6.9: Need to learn*

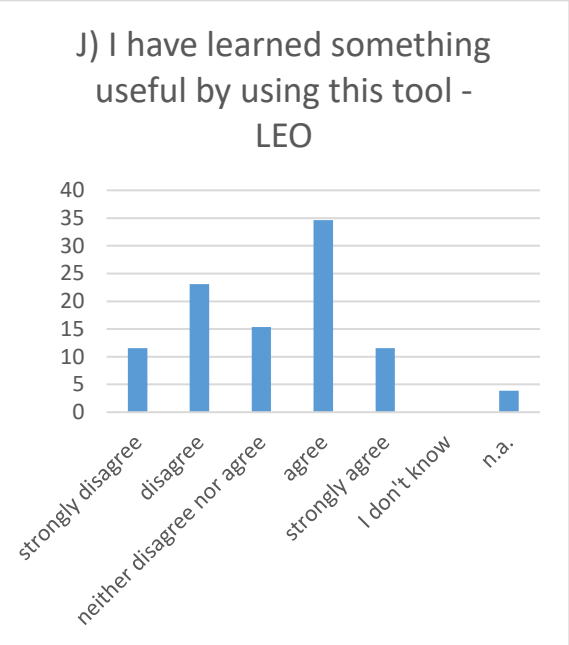


*Figure 6.10: Learning effect*

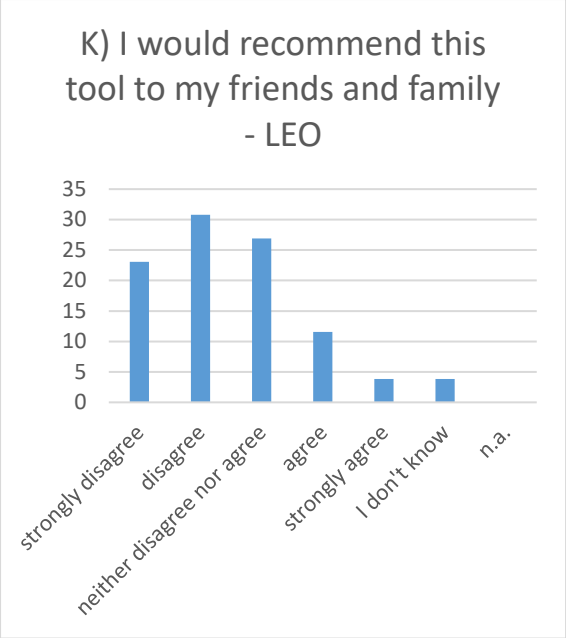


*Figure 6.11: Recommend LEO to family & friends*

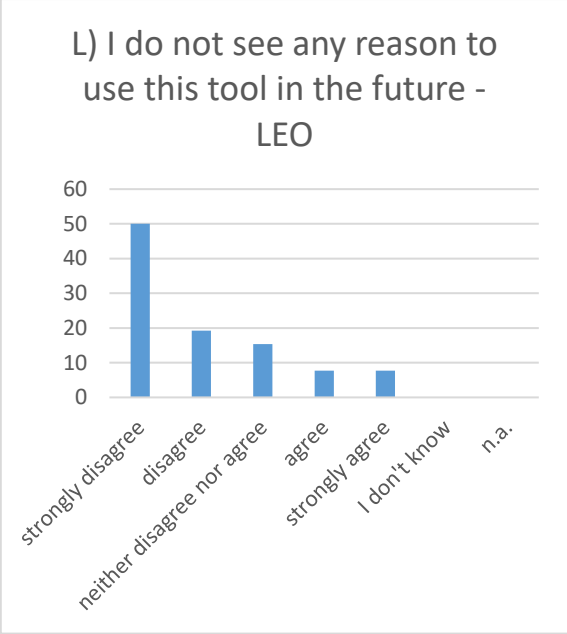


*Figure 6.12: Future use of LEO*

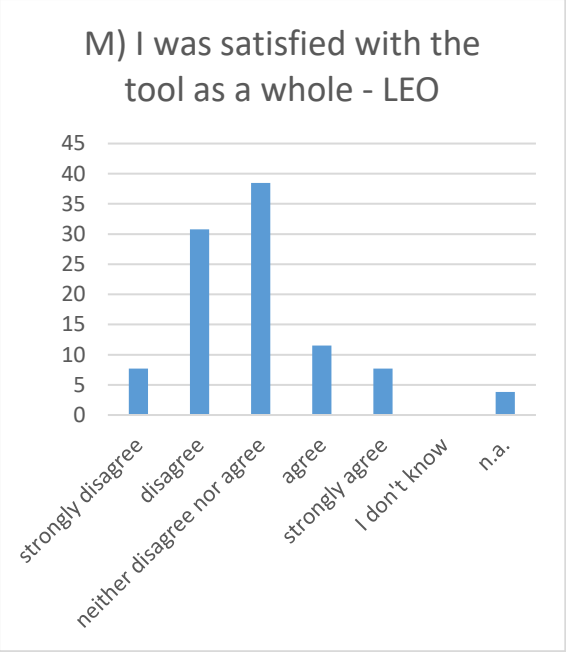


*Figure 6.13: Satisfaction with LEO*

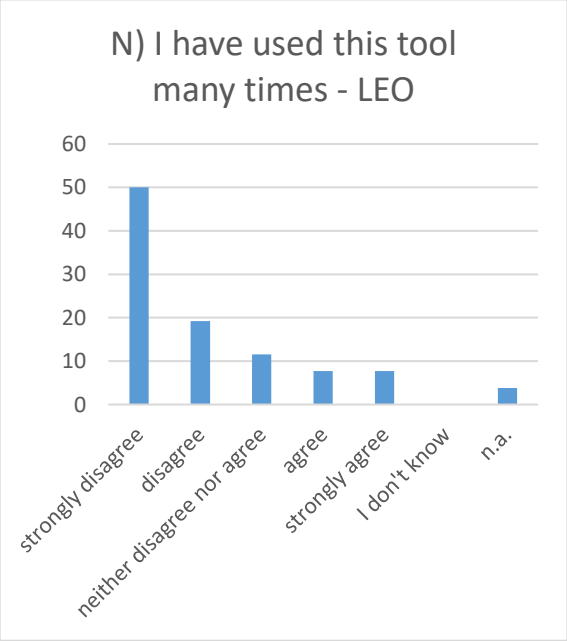


*Figure 6.14: Use of LEO*

### 6.3 On-line Air Quality Perception Questionnaire

For the On-line Air Quality Perception Questionnaire, none of the volunteers has filled in a form of the user evaluation questionnaire. However, we have carried out an interview with a representative from the municipal authorities (Oslo Kommune – Bymiljøetaten) where we discussed the use of such a tool. As it turned out, the municipality considers the results are "nice to know", but do not really bring any new information that has not been available from before. There have been many similar surveys carried out with tools that are already (freely)

available and there is no need for further surveys. They commented it is now the time to use the information derived from the questionnaire and act upon that.

We also carried out an interview with two representative from NAAF (Norwegian Asthma and Allergy Association). They find the questionnaire very useful as it reflects the opinion of the citizens regarding an important topic as it is air pollution. From their point of view, the results from the questionnaire can be used as an evidence to force authorities to improve air quality in Oslo.

### 6.4 CityAir Smartphone App

Out of the 195 people that have downloaded the app to their smartphone, only 12 people completed the usability evaluation questionnaire. Six of them were male and 6 female. The participants evaluating the CityAir app were between 28 and 56 years old. 75% completed a master degree, 25% undergraduate studies. All of the volunteers live and/or work in Oslo and they are all (very) much interested in the topic of air quality.

More than half (58%) of the volunteers evaluating the CityAir app agree that they would like to use it frequently, although one quarter would neither agree nor disagree to this statement (Fig 6.15). The majority (75%) of the volunteers thought CityAir was not unnecessarily complex (Fig 6.16). Sixty-seven percent thought the app was easy to use (Fig 6.17) and 83% stated they would not need technical support to be able to use the app (Fig 6.18).

Regarding the integration of CityAir's various functions the volunteers seemed to be somewhat indecisive. Although 42% of the users agreed to the statement, one quarter did not and 17% did neither agree nor disagree and also 17% did not know (Fig 6.19). However, 50% thought that there was not too much inconsistency in the system (Fig 6.20). Eighty-three percent of the users that completed the evaluation found it easy to learn how to use the app, and 67% felt very confident using this tool (Fig 6.21). Seventy-five percent stated that they did not need to learn a lot of things before using the CityAir app (Fig 6.22).

Although 75% state that they did not need to learn a lot of things before using the app (Fig 6.23), it did not contribute much to the learning process. Thirty-three percent of the users declared that they have not learned anything useful by using the app, 25% neither agreed nor disagreed, only 25% have learned something useful and 17% did not know (Fig 6.24).

Although 44% of the users would recommend CityAir to their friends and family, 25% were undecided and 33% would not (Fig 6.25). However, 58% of the participants would use the app in the future (Fig 6.26). Similarly, 58% report their satisfaction with the CityAir app as a whole, although as many as 25% disagree (Fig 6.27). Fifty percent of the volunteers have not used the app many times (Fig 6.28).

Fifty percent respondents considered the most useful aspect of the CityAir app that it can visualize pollution ("You can see pollution where you are living"). The option to see the perception of other people was mentioned by only 13% ("To see how others assessed it, to see results from others, to be able to influence"). As most disappointing aspect 38% claimed technical problems ("Difficult to see if you have registered/saved what you typed in"), 50% commented on different issues (e.g., difficult to see the pollution sources, very subjective, or being afraid of "over-/underreporting"). Only one comment was provided regarding technical improvement and one about the density of data.

In summary, most participants reported positive experiences with the CityAir app and were satisfied with the tool as a whole. According to their judgment, the app was easy to use, not too complex, easy to learn how to use and various functions were well integrated. People felt confident using the app and did not require any technical support to use it. Although they were content with the app per se, the majority of the participants did not learn anything useful using it and admitted that they have not been using it many times. This might indicate that the majority of the participants that submitted the evaluation form did not feel the need for such an app.

In addition to the User Evaluation Questionnaire, we have also conducted an interview with two representatives from NAAF to receive more information about the users' perception of the CityAir app. They found the CityAir app to be an interesting tool to give voice to the people in a more interactive way than a survey. The app could be extended to cover other parameters as for example respiratory symptoms experienced by people, that could help other people with similar problems to avoid certain areas or be more aware or the possible risks.

We also had a short interview with a representative from the local authorities (Oslo Kommune – Bymiljøetaten). The representative did not see any specific use for the CityAir app. Personal perception seems to be uncertain information that the municipalities do not see much added value in when collected from a random and unspecified group of people somewhat continuous like in an app. One main factor for representativeness will be the number of people participating and their background.

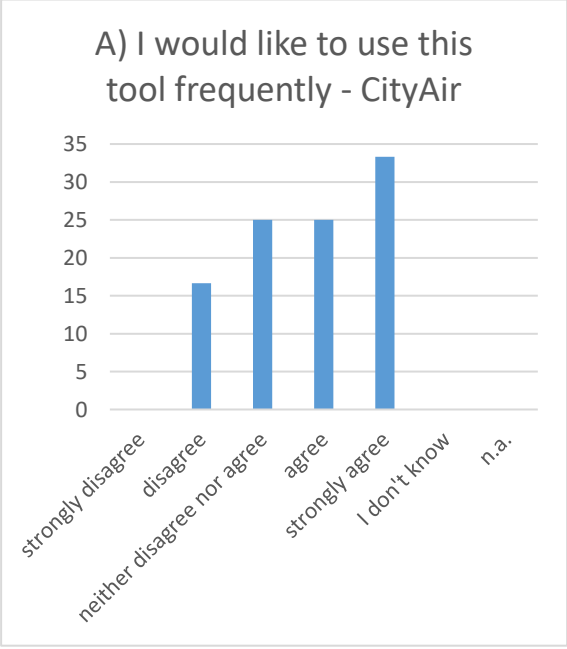


*Figure 6.15: More frequent use of CityAir*

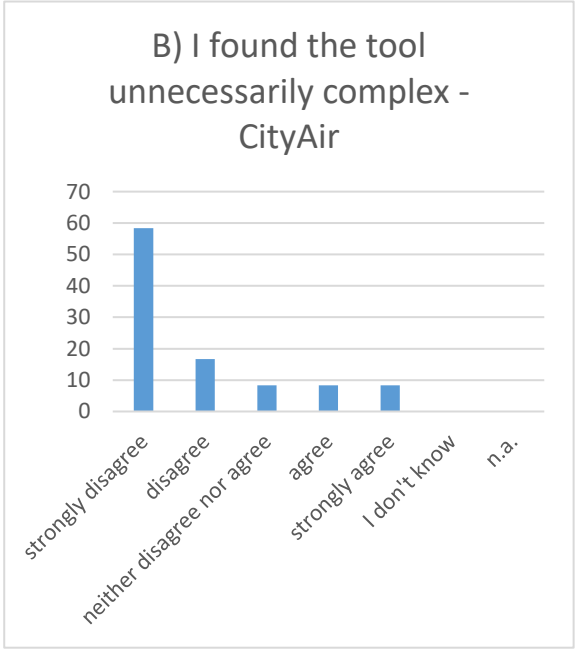


*Figure 6.16: Complexity of the CityAir*

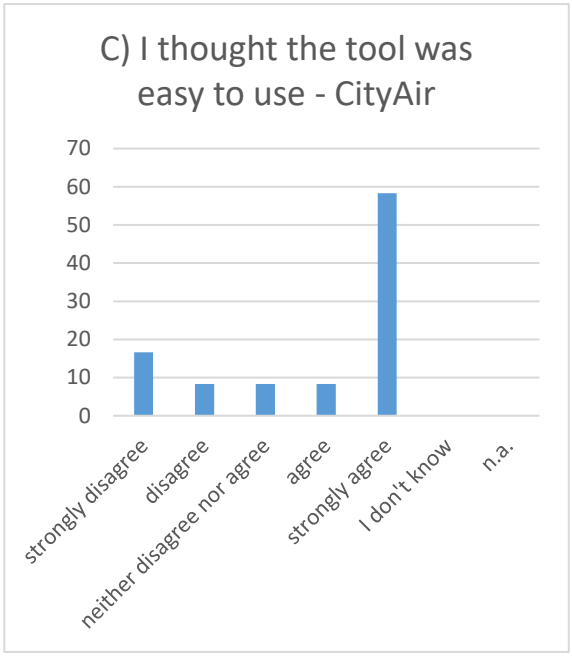


*Figure 6.17: Easiness of use*

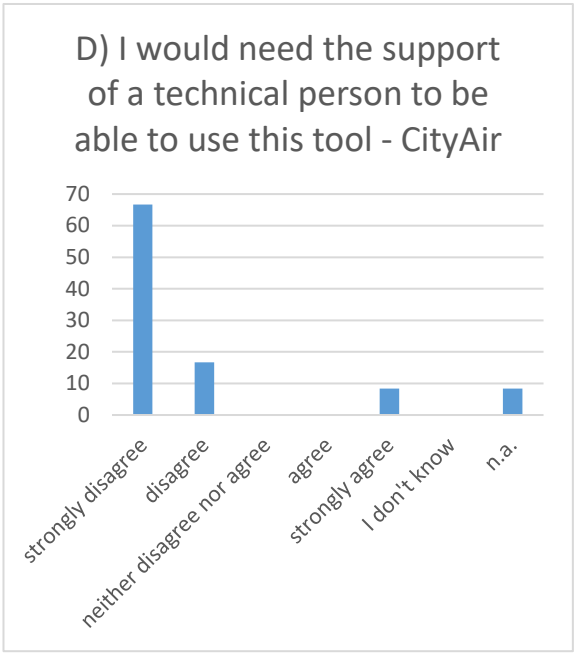


*Figure 6.18: Support of a technical person*

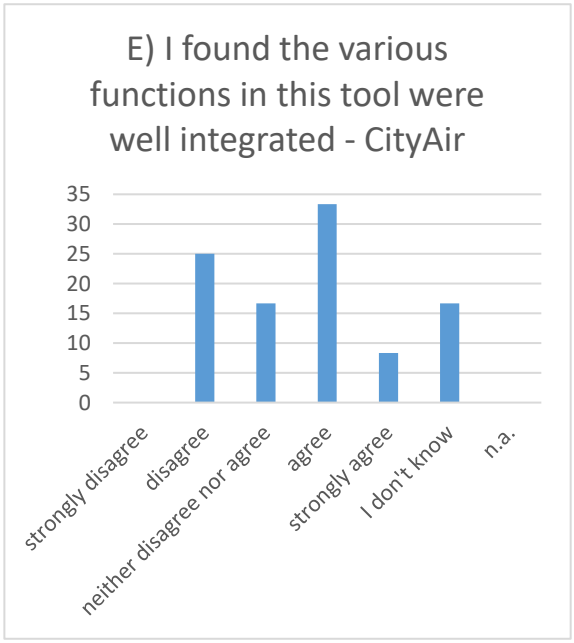


*Figure 6.19: Integration of various functions*

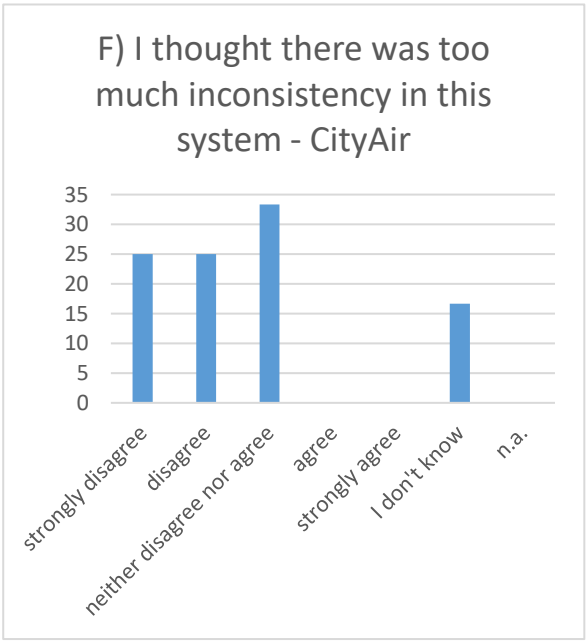


*Figure 6.20: Inconsistency within CityAir*

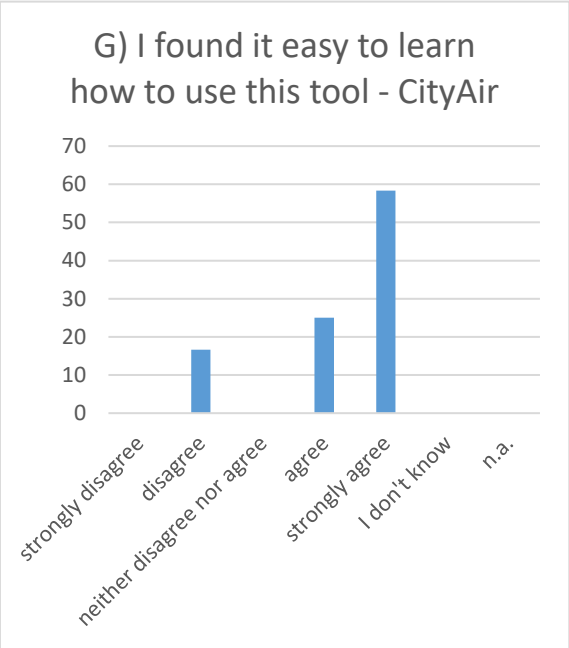


*Figure 6.21: Easiness to learn to use*

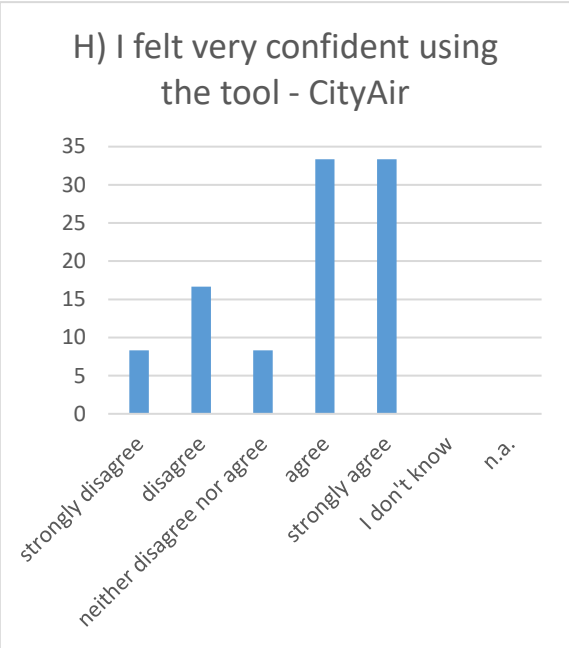


*Figure 6.22: Confidence in using CityAir*

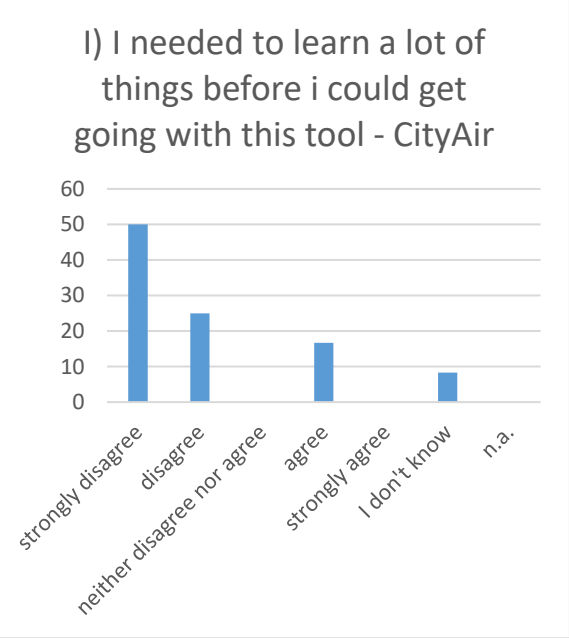


*Figure 6.23: Need to learn*

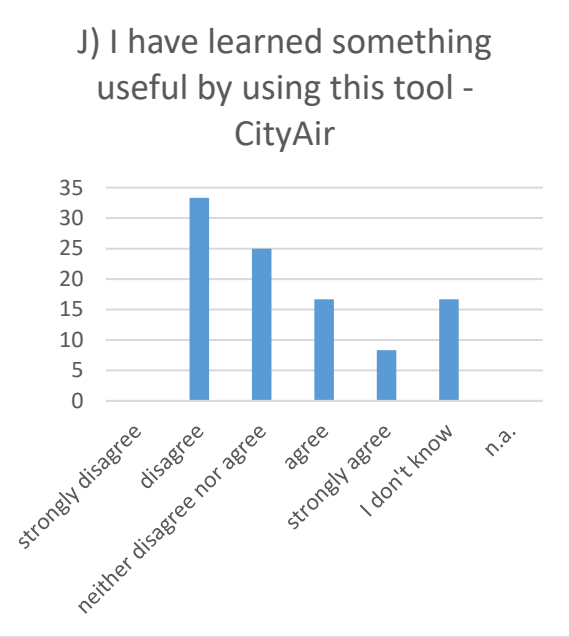


*Figure 6.24: Learning effect*

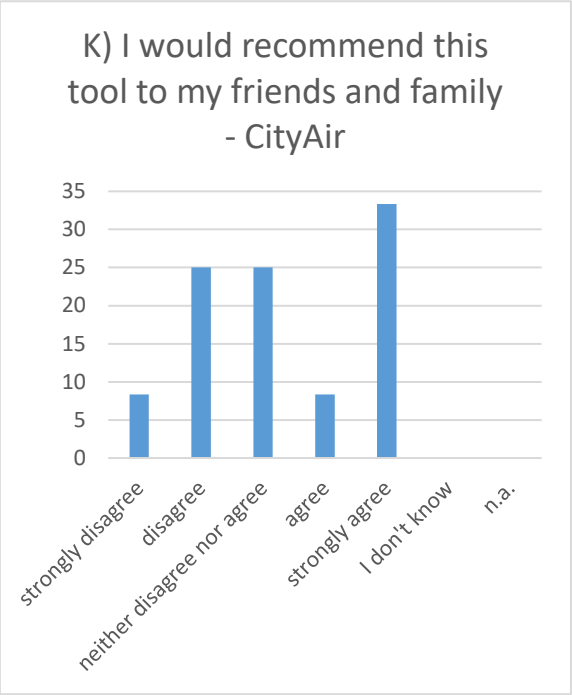


*Figure 6.25: Recommend CityAir to family & friends*

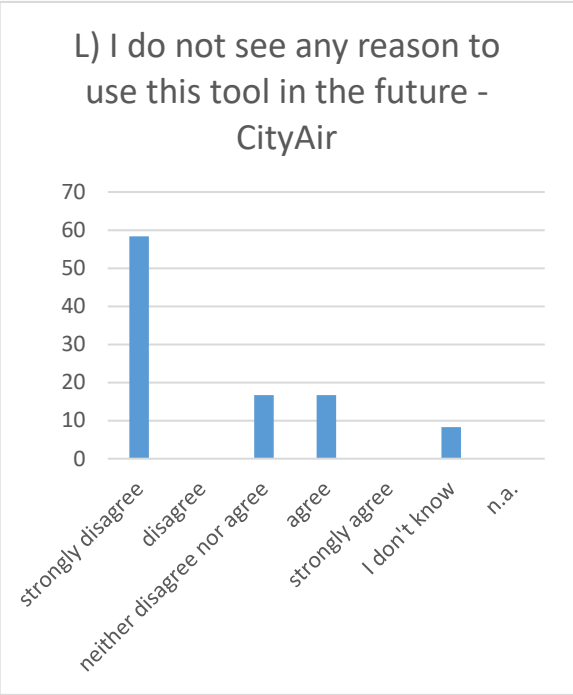


*Figure 6.26: Future use of CityAir*

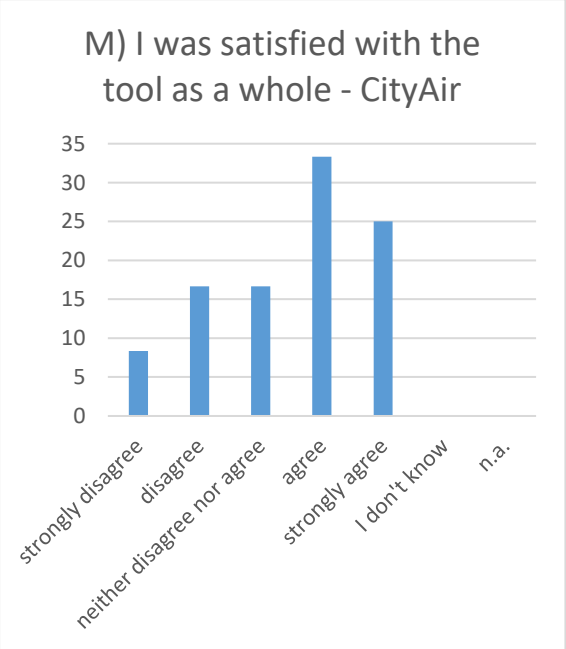


*Figure 6.27: Satisfaction with CityAir*

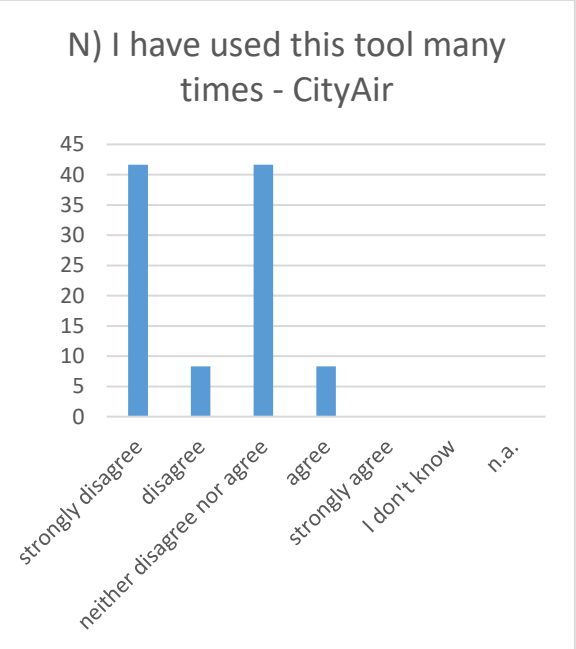


*Figure 6.28: Use of CityAir*

# 7 Conclusions

The technology used in CITI-SENSE to monitor air pollution is still in an early stage of development. This means that the air quality monitoring data we obtained cannot be used directly by the citizens due to their high uncertainty. In general, the data we obtained requires complex data analysis that for the time being can only be carried out by experts.

Nevertheless, this project has demonstrated the potential that lies within the new sensor technology, that may soon be realized due to the rapid development. In the coming years, low-cost sensors are likely to become more reliable and deliver much more robust data.

CITI-SENSE has involved the public in testing new technologies to monitor air pollution. We have seen that it is necessary to involve people as early as possible as they will be the ones using those technologies. We need their input and feedback since it is they who know what they need. Instead of presenting citizens a range of great solutions that might not necessarily be the response to their problems, we should rather focus on the problem and find solutions together with the affected citizens. They can then help us in testing our technologies and provide feedback in order to improve them.

In CITI-SENSE, we not only focused on testing new technologies, but also on understanding how people in Oslo perceive outdoor air quality. For that purpose, we have used two tools: an on-line questionnaire to assess more in-depth perception of air quality, and a mobile application (CityAir) to evaluate the spatial and temporal variation of air quality perception and its relation with the physical pollution levels and the surroundings.

The results from the survey showed that the participating citizens are very interested in air quality, and most of them think that air quality is affecting their health. Despite that fact, the results show also that almost half of the respondents do not consider air quality levels at all or very little when moving in the city and that they actually do not look at air quality information on a regular basis. Some of the possible causes can be found in the fact that half of the respondents claim that “I don’t know where to find the information but I am interested in it” and that “air quality information is slightly or moderately useful”.

The results from the CityAir perception app indicated that it is difficult for people to assess for themselves whether air pollution is “good” or not. The results show that perception of air quality is unrelated to the real exposure. For example, on days when air pollution was classified as moderate or high based on municipal monitoring stations, more than 50% reported “air quality is very good”.

The fact that exposure to particulate matter has adverse effects on health and that, according to the results, people cannot easily perceive when and where the levels are high, makes it even more important to create tools to inform the public appropriate to the task of providing actionable information. Based on the results of the survey, it will be necessary to ensure that the information reaches the public, especially on the days with high pollution levels. At the present time, most people do not consult air quality information on a regular basis.

The final aim should be to reduce air pollution to levels that do not pose a risk for health. For the majority of the respondents, authorities are the group that has more power to solve air pollution problems. However, half of the respondents indicated that citizens have also a responsibility to improve the air quality.

The results show furthermore that the respondents are ready to adopt measures to improve air quality. The majority of the respondents replied that they do have the capacity to take steps to improve air quality. Moreover, the majority of the participants think that citizens should be involved in policy-making, through public surveys, participation in meetings and on-line discussions and via elections and referendums. In the interview with the local authorities they confirm that in Norway there are regulations for public participation and depending on the topic different methods are employed.

The combination of in-depth surveys and information on perception linked to space and time improves our knowledge on outdoor air quality perception in the population. A better understanding of the perception can help to develop targeted outreach campaigns to influence the public acceptance of environmental policy and to form a clearer picture of how local context influences the opinion. However, it is important to reach a sufficient number of users so the results are representative.

Engaging people to participate in Citizen Science or Citizens' Observatories initiatives can also be a challenge. According to our experience, people that are either personally affected or generally interested in the topic of air pollution, were more likely to engage in our project activities. Nevertheless, is it difficult to keep up the participants' interest over a longer period, especially if the technical equipment is not working correctly. Easy to use devices with low technical threshold that are running smoothly and can be easily implemented into people's daily routines can keep up the volunteers' interest. Also, regularly provided information and feedback about the measurements and project progress, as well as transparent project work will help to keep people engaged. When visualizing and communicating data or results, we have to ensure that they are communicated in a way that people actually understand what they are about and what they mean for the environment, people's daily life and their health.

# 8 Acknowledgements

CITI-SENSE, www.citi-sense.eu, has received funding from the European Union's Seventh Framework Programme for Research, Technological development and Demonstration under Grant Agreement no 308524.

The AQMesh units were provided by Environmental Instruments Ltd. (www.aqmesh.com). The LEO units were provided by Ateknea Solutions (www.ateknea.com)

The CityAir app has been developed in collaboration with the EMMIA project Citi-Sense-MOB and NTNU Gjøvik.

We would like to thank all the volunteers that participated in the project and those citizens that follow the project on social media. We would like also to thank our colleagues that participated in the CITI-SENSE activities.

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# Appendix A

# Links to the on-line air quality survey and CityAir mobile application

The On-Line Air Quality Perception Questionnaire can be used in campaigns to assess in-depth perception of air quality and get feedback. The online perception questionnaire is available in different languages for each city that is involved in CITI-SENSE. The user can answer the questionnaire on a webpage, mobile phone or tablet. The Table has the links and the QR-code to access to the on-line questionnaire for the city of Oslo. The questionnaire is available in Norwegian and in English.

*Table A.1: Links and QR-code to access to the on-line air quality perception questionnaire.*

| City | Web page questionnaire | QR access code |
|---|---|---|
| Oslo | **Norwegian**: http://w.civicflow.com/task/participate/153<br><br>**English**: http://w.civicflow.com/task/participate/150 | |

CityAir is a smartphone application (App) for the public to express their perception of the outdoor air quality at their location. It allows users to collect and display individual perceptions of air quality, irrespective of where they are in the world. It also allows users to indicate the assumed source of the air pollution and write a comment. CityAir app is available for Android (https://play.google.com/store/apps/details?id=io.cordova.CityAir) and Iphone (https://itunes.apple.com/no/app/cityair-perception/id1045646666?mt=8).

# Appendix B

# On-Line Air Quality Perception Questionnaire (English version)

**Introduction text**

CITI-SENSE is a European project which aims to give citizens like you a better "sense" of the air quality in cities by using new technologies. The CITI-SENSE team would like to help you to find out more about the air quality where you are and how to act on the information. You can read more about the project at www.citi-sense.eu and www.oslo.citi-sense.eu.

This questionnaire is part of the CITI-SENSE project and will help us to understand more about how citizens like you perceive air quality issues in Oslo.

The questionnaire is completely anonymous. We will collate all the responses and make the results publicly available. You can see the results from Oslo at the local web page (www.oslo.citi-sense.eu), and the results from the other CITI-SENSE participant cities in the central web portal of the project (co.citi-sense.eu). We also invite you to follow us on facebook (#oslocitizensobservatory)

Please take the time to complete this short questionnaire. It will only take 5-10 minutes of your time.

Thank you for your support!

If you have any further questions on the subject, you can contact us at any time at oslo_co@nilu.no

Sincerely,

Your CITI-SENSE OSLO team!

## About you

1) **What gender are you?**
    a. Male
    b. Female
2) **What year were you born (please use by 4 digits)?**
    a) YYYY (write the year here)
3) **What is the highest level of education have you completed to date?**
    a. Primary school
    b. Secondary school
    c. Undergraduate degree (University/college)
    d. Master degree
    e. Doctorate degree or higher
4) **What do you do in Oslo? (tick all that apply)**
    a. Live
    b. Work
    c. Study
    d. Other
5) **How interested are you in air quality in general?**
    a. Not at all interested
    b. Slightly interested
    c. Moderately interested
    d. Very interested

## What do you think about the air quality in Oslo?

6) **How would you describe the air quality in Oslo in general?**
    a. Very poor
    b. Quite poor
    c. Quite good
    d. Very good
    e. I don't know
7) **In relation to the previous question, could you please explain briefly why you chose this option? (optional)**

## How air quality affects your health

8) **To what extent do you think that the air quality in Oslo affects your health?**
    a. Not at all
    b. A little
    c. Moderately
    d. A lot
    e. I don't know
9) **Do you consider air quality when moving around in Oslo (e.g., avoid to cycle in busy roads, not working out if air quality is bad, etc.)?**
    a) Not at all
    b) A little
    c) Moderately
    d) A lot
    e) I don't know

## What do you think about accessibility to air quality information in Oslo?

**10) How often do you consciously look at air quality information (e.g., in television, newspapers, internet)?**

a. Never
b. About once per year
c. About once per month
d. About once per week
e. Most days

**11) If you have answered "Never" in the previous question, why do you never look at air quality information?**

a. There is no air quality information for Oslo.
b. I don't know where to find the information, but I am interested in it
c. I don't know where to find the information and I am not interested in it
d. I know where to find the information but I am not interested in it
e. Other. Please indicate: _____

**12) Do you think the information on air quality in <Oslo> is useful to you?**

a. Not at all useful
b. Slightly useful
c. Moderately useful
d. Very useful
e. I don't know

## Who can improve air quality in Oslo?

**13) In your opinion, who are the 3 groups that can contribute the most to improving the air quality in Oslo? (select a maximum of 3 options; In the following question (14) you can add the type of action you have in mind for each of the group selected by you)**

a. Industry and commerce
b. The municipality (e.g., city council)
c. Regional and central governmental bodies
d. People who spend most of their time in the city (e.g., residents, workers, students)
e. Scientists
f. Commuters
g. Other. Please indicate: _____

**14) In relation to the previous question, can you please add the type of contribution you have in mind for each of the 3 groups you selected; e.g. creating air quality laws, lowering emissions, political actions, supply information about air quality problems, … (optional)**

_____

**15) How do you think citizens should participate in policy-making on urban air quality? (select a maximum of 3 options)**

a. Via public surveys
b. Via participation in public meetings and hearings
c. As members of citizen advisory committees

d. Via open online discussions (e.g., web forums, mobile phone apps, social media, etc.)
e. Via a referendum
f. Via voting in elections
g. Citizens should not be involved
h. Other. Please indicate: _____

**16) What steps do you think you would personally take to help improve air quality in Oslo? (you can select more than one option)**

a. Use more environmentally-friendly transport options (e.g., public transport, , cycle, car sharing)
b. Get involved in policy-making (e.g., via public surveys, citizen advisory committees)
c. Use environmentally-friendly systems at home (e.g., renewable energies, electric heating instead of wood burning)
d. I don't have the capacity to take any steps to improve air quality
e. Other. Please indicate: _____

## Give us your feedback

1) **Do you have any comments or suggestions about air quality in Oslo you'd like to share with us? (optional)**

_____

**We also have two extra, more detailed questions on how would you may like to receive air quality information. If you still have some time, your contribution would be really helpful! If not, thanks for answering this section!**

- Yes, I would like to help.
- No, I don't have time now.

## Optional questions on air quality information for the public:

1) **In which format would you prefer to receive air quality information? (select a maximum of 3 options)**
   - Mobile phone application (e.g App)
   - Website
   - Social media (e.g. twitter, facebook)
   - Radio information
   - Information panels (e.g. in the main squares, in the public transport, etc.)
   - Flyers
   - Newspaper articles
   - Television adverts
   - Other. Please indicate which: _____

2) **If you could have an application mobile phone App which informs you about air quality, how important would it be to have the following features?**(5 point scale (bullet points): not a priority, low priority, medium priority, high priority, essential)
   - Air quality in your immediate vicinity (i.e. where you are)
   - Numeric information on pollutant concentrations in the air
   - An air quality index indicating if the air quality is poor or good
   - Ability to report what you think the air quality is like
   - Ability to see what other users have reported
   - Information on past air quality
   - Information on current air quality
   - Information on forecasted air quality
   - Information on what to do to protect your health
   - Notifications in case of increased air pollution
   - Possibility to see the air quality levels in the routes you move around the city
   - Possibility to select cleaner routes to move in the city

**3)** In relation with the previous question, are there any other features you would like to have in a mobile app to be informed about air quality? (Optional question)

_____

**You have now completed our questionnaire, many thanks for taking the time to do so!**

Interested in learning more about our project? Please visit www.oslo.citi-sense.eu.

If you would like to be informed when the results of this survey are available, collaborate with future questionnaires, participate as citizen scientist in the project or learn more about the project, please contact us on oslo_co@nilu.no.

Thank you again for your interest in CITI-SENSE!

## NILU – Norwegian Institute for Air Research

NILU – Norwegian Institute for Air Research is an independent, nonprofit institution established in 1969. Through its research NILU increases the understanding of climate change, of the composition of the atmosphere, of air quality and of hazardous substances. Based on its research, NILU markets integrated services and products within analyzing, monitoring and consulting. NILU is concerned with increasing public awareness about climate change and environmental pollution.

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