Monitoring for a healthy city

Citizen Science and Air Quality

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Go to www.slimmeengezondestad.nl for further information.

Authors RIVM - Joost Wesseling, Annemarie van Alphen, Hester Volten, Edith van Putten
Smart and Healthy City Programme Ministry of Infrastructure and the Environment – Evelyn Hijink
Editing SME Advies – Bregje van den Brand and Noortje Brookhuis
Design and lay-out Punt Grafisch Ontwerp

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Rijksinstituut voor Volksgezondheid en Milieu
Ministerie van Volksgezondheid, Welzijn en Sport

Ministerie van Infrastructuur en Milieu

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1. Introduction

Air quality and health effects

Air quality has a direct effect on human health. Poor air quality can cause or contribute to cardiovascular and respiratory conditions, reducing life expectancy by several months. The European Union has set air quality standards which it has made mandatory by means of directives. The Netherlands has adopted these standards and has implemented the directives within its national legislation.
In all but a few (mostly) urban locations, our country now meets the European air quality standards. A monitoring system is in place to ensure that it continues to do so, and to gain a better understanding of air quality at various locations and various times. At the national level, measurements and analyses are conducted by the National Institute for Public Health and the Environment (RIVM), in which knowledge of air quality is combined with knowledge concerning the health impact of air pollution.

Pollutants and their sources

This brochure is chiefly concerned with specific air pollutants: nitrogen dioxide (NO_2), particulate matter (PM_{10}, $PM_{2,5}$), ultrafine particles (UFP, defined as particulate matter of less than 100 nanometres in diameter) and elemental carbon (EC), or soot).

These pollutants have various sources. Road vehicles make a substantial contribution to air pollution, but industry, livestock farming and domestic energy consumption also play a part. There are also natural sources of air pollution, such as salt mist in the coastal regions and airborne soil particles. Some of the pollutants in our air stem from other countries and are carried here by the wind. A more detailed account of pollutants, sources and effects can be found in Chapter 3.

"To measure is to know"

Many factors determine what pollutants are to be found in the atmosphere and in what concentrations. They include location, time, the weather, the proximity to the source and the emission activity of that source. There are monitoring stations throughout the Netherlands which measure the concentrations of the various pollutants. The more data we have, the easier it becomes to make accurate statements regarding air quality and to implement appropriate measures. Data from the monitoring stations is also used to calibrate the simulation models on which projections are based. Traditionally, air quality has been measured using specialist equipment installed at permanent monitoring stations. The maintenance of the stations and their equipment is both complex and expensive.

How can you help

Recent years have seen a new development whereby members of the public have become involved in measuring air quality. Because they can do so in places which are inaccessible to the scientists – a private garden or balcony, for example – the information they produce is a valuable supplement to the ‘official’ data. Perhaps the new information will reveal a specific, very localized problem. If so, targeted action can be taken.

This brochure includes several examples of this ‘Citizen Science’ at work. We look at projects in which members of the public are helping to measure air quality in Dutch towns and cities. These volunteers are making a significant contribution to various scientific research programmes. Further information about RIVM’s air quality monitoring programme can be found at https://www.samenmetenaanluchtkwaliteit.nl/ (in Dutch). The site also includes links to other Citizen Science resources.

2. Citizen Science

The emergence of Citizen Science

Man has been studying his environment for thousands of years, making observations and analyses in areas such as meteorology (climate and weather), hydrology (water management) and ecology (wildlife and nature). The resultant data, collected over time, gives us a greater understanding of how the world is changing. Since the 19th century, the task of measuring and monitoring has fallen to scientific institutions, often working on the instructions of the government.

Recent years have brought a new development whereby the general public is closely involved in research. 'Enthusiastic amateurs' contribute specialist knowledge, creativity, additional computing capacity, financial resources and manpower to support scientific endeavour. They may even lead research projects. The citizen can be involved in all stages of the research process, from defining the objectives to analysing the results. In many cases, public input enables a greater volume of research data to be collected over a wider geographic area. Collaboration between the amateurs and the professionals results in a far greater body of knowledge, which is available to all.

Huge potential

It seems likely that Citizen Science will continue to develop apace. Smaller and less expensive sensors will become widely available, while modern information technology will facilitate the collection and storage of data. Citizen Science makes it possible to conduct research on a much larger scale without incurring any additional costs. Inaccurate or unreliable data can be identified and excluded. Even where individual readings have a high degree of uncertainty, the average should be reasonably close to that derived from precision instruments. Citizen Science encourages creativity. It offers a platform which supports critical appraisal. Citizen Science promotes cooperation at home and abroad. It brings science and society closer together.

Smart Emission in Nijmegen

The Smart Emission project is a joint initiative set up by City of Nijmegen, Radboud University, Geonovum, CityGis , Intemo and RIVM. A network of low-cost sensors is used to measure air quality at the local level, whereupon variations in location and time can be identified and tracked. The project brings together public sector authorities, research institutes and the general public. An announcement in a local newspaper had a significant response and around twenty sensors have been installed in private gardens or on the exterior of residential properties.

One objective of the study is to assess the value of data collected in this way. How much does it add to the information gathered by the RIVM monitoring programme? The project is also examining new 'smart' ways of using the data to support behaviour change. It devotes attention to how the various partners can and should use new forms of open data, the 'democratization' of knowledge, the participative society and 'bottom-up' planning processes.

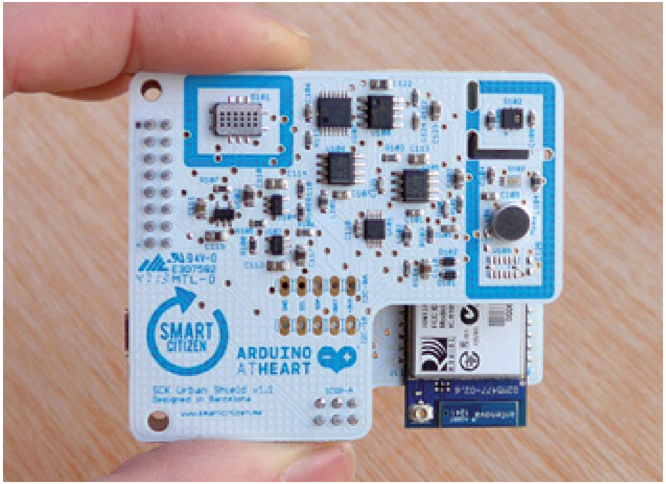
Smart Emission is a prime example of a Citizen Science project which brings together many diverse and seemingly disparate partners. It offers a chance to test new technologies and promote the use of those which prove worthwhile. The city authority gains a better understanding of the air pollution issues in its area and can explore new ways of tackling those issues with the help of the local populace. The knowledge institutes not only gain additional data but improve their public outreach.

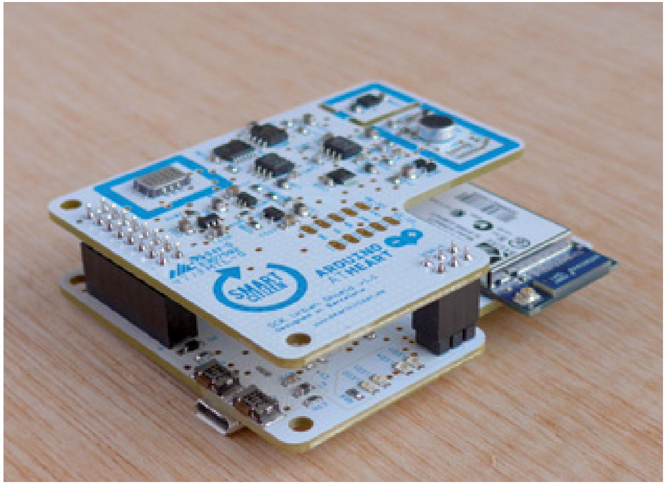
Air quality monitoring and policy

Air quality is closely monitored throughout Europe to ensure that the statutory targets are met. The management and maintenance of this type of monitoring is expensive. The Netherlands has a network of almost one hundred 'official' monitoring stations. To create an even more detailed picture of air quality, members of the public can contribute to the process of data collection. Citizen Science projects offer opportunities for closer interaction between government authorities and the man in the street. Citizen Science can be applied at local and national level to support decision-making and policy formulation.

Why is Citizen Science so interesting?

- For science: people enjoy contributing to human knowledge.
- Personal interests: to protect and improve one's own environment and health.
- Verification: to 'double-check' information provided by the government and official agencies.
- Information: local monitoring is most relevant to the individual.
- The Open Data policy: helping to support the government's drive for transparency.





Smart Citizen Lab Amsterdam

In 2014, Amsterdam's Waag Society handed out 'Smart Citizen Kits' to seventy local volunteers (see photos above). The kits comprised open source measuring systems for carbon monoxide (CO), nitrogen dioxide, (NO2), temperature, relative humidity, light intensity and environmental noise. Data was collated and analysed by experts who also provided support as necessary throughout the project.

The Smart Citizen Lab project has provided several useful insights. First, people enjoy learning more about their environment and are keen to help improve that environment by taking an active part in monitoring the variables. Second, a Citizen Science project should be based on monitoring equipment which is simple to use, robust and appropriate to the level of scale concerned. These 'lessons learnt' were carried over into the Making Sense project which was launched in Amsterdam, Barcelona and Kosovo in 2016.

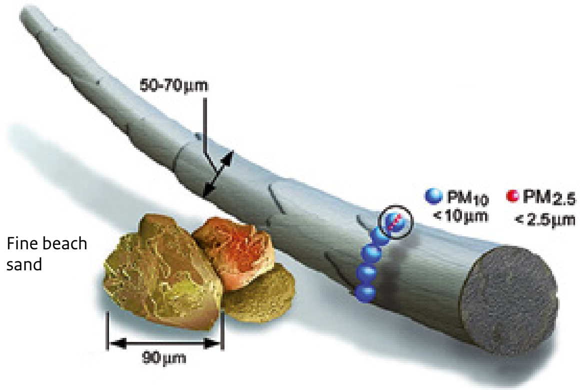
3. What determines air quality?

The table below gives an overview of the substances which determine air quality, their sources and potential effects. The table also shows the legislative standards (upper limits) and the current average values measured in the Netherlands.

		Particulate matter			
	Nitrogen dioxide (NO_2)	**Particulate matter (PM_{10})**	**Fine Particulate Matter ($PM_{2,5}$)**	**Ultrafine Particles (UFP)**	**Elemental carbon (EC) / Black carbon (BC)**
What is it?	A gas.	Generic term for particles in the atmosphere with a diameter less than 10 micron (µm).	Particles with a diameter less than 2.5 µm.	Particles with a diameter less than 0.1 µm.	'Soot' formed by the incomplete combustion of fossil fuels and/or the bonding of ultrafine particles.
Sources	(Chiefly) road traffic and industry.	Road traffic, combustion, livestock farming and natural sources.	Road traffic, combustion, and natural sources.	Road traffic, combustion, natural sources and aviation (during take-off and landing).	(Chiefly) road traffic.
Effects	Lung irritation, compromised immunity, respiratory infections. Long-term exposure to current NO_2 levels will reduce average life expectancy by four months.	Long-term exposure to current levels will reduce average life expectancy by nine months.	Long-term exposure to current levels will reduce average life expectancy by nine months.	Exposure to extremely high concentrations of ultrafine particles causes (temporary) cardiovascular effects and respiratory impairment. Long-term effects are currently unclear.	Long-term exposure is likely to reduce average life expectancy by three months for each additional 0.5 µg EC/BC.

		Particulate matter			
	Nitrogen dioxide (NO_2)	**Particulate matter (PM_{10})**	**Fine Particulate Matter ($PM_{2,5}$)**	**Ultrafine Particles (UFP)**	**Elemental carbon (EC) / Black carbon (BC)**
Legislative standard (upper limit)	Annual average: 40 µg/m³. Hourly average 200 µg/m³ (with no more than 18 exceedances p.a.)	Annual average: 40 µg/m³. Per 24 hour period) 50 µg/m³ (with no more than 35 exceedances p.a.)	Annual average: 25 µg/m³. 20 µg/m³ from 2020.	None at present.	None at present.
Current values in NL	2014 Dutch national average > 15 µg/m³. Randstad: 22-25 µg/m³. Some measurements taken alongside trunk routes and urban areas exceed the 40 µg/m³ limit.	Average concentrations vary between 18 µg/m³ (northern Netherlands) and 22 µg/m³ (major cities, southern Netherlands).	Concentrations range from 11 µg/m³ to 15 µg/m³ with an average of approximately 12 µg/m³.	Hourly average above 5,000 particles per cm³ and in extreme cases up to 100,000 particles per cm³.	Average concentration alongside busy roads is 1.5-2.0 µg/m³. The average in urban areas is 0.9-1.5 µg/m³. Elsewhere it is 0.5-1.0 µg/m³.
Monitoring requirements and maximum uncertainty	The average uncertainty over a longer period (of several weeks) must not exceed 10 µg/m³.	Daily averages must be calculated whereupon it is important to distinguish between high(er) readings (30-50 µg/m³) and low(er) readings (10-20 µg/m³).	PM2.5 concentrations are always slightly lower than those of PM10. The measurement uncertainties should be the same in both cases PM10.	There is no legal limit so no maximum uncertainty is defined. The uncertainty should allow to detect variations at the desired time scale.	There is no legal limit so no maximum uncertainty is defined. The uncertainty should allow to detect variations at the desired time scale.

Human hair



Basic figure: EPA (USA)

Units

Various units are used to express the quantity or concentration of a substance in the atmosphere. In Europe, one of the most common units used to indicate overall air quality is “micrograms per cubic metre” (µg/m³). In some cases, especially in safety applications which deal with far higher concentrations measured over a brief period of time, the unit “milligrams per cubic metre” may be used. (A milligram is 1000 microgram).
Other common units include “parts per billion (ppb) and “parts per million” (ppm) both of which are used to indicate the concentration of gases.
If a sensor is to be of any value in measuring air quality it must show either ppb or µg/m³.
There is a general conversion formula: **µg/m³ = (ppb)*(12.187)*(M) / (273.15 + °C)** where M is the molecular weight of the gas concerned.
For example 1 ppb NO_2 (at a pressure of 1 atmosphere and a temperature of 15 °C) is equivalent to 1.95 µg/m³.

4. Different types of sensor

This section offers some general information about the methods and equipment now available to Citizen Science projects. Sensor technology continues to develop. For up-to-date information, including vendors and approximate prices, see https://www.samenmetenaanluchtkwaliteit.nl/.

The quality of measurements

All sensors, regardless of price, can show 'aberrant values'. These are unexpected readings which may not give an accurate impression of the actual situation. It is important that sensors are regularly calibrated and that the people using them can recognize aberrant values, perhaps by comparing their results with those of an official monitoring station. One of the challenges facing Citizen Science is to ensure the quality and reliability of the various sensors in use. This is something to which RIVM will devote attention in the months and years ahead. It is in general good to compare your results to those of others.

External factors

The results produced by the sensors can be influenced by various external or secondary factors: temperature, wind, air pressure, shade and relative humidity, for example. The ambient temperature has a particularly marked effect on the performance of some sensors and hence on the results they produce. Users should attempt to minimize the influence of external factors. This will greatly enhance the quality and usefulness of their data. Ideally, a sensor should be mounted free of all obstructions, at least 0.5 to 1 metre from any wall and one or two metres above the ground.

Palmes diffusion tubes

Palmes diffusion tubes are used to measure the atmospheric concentration of nitrogen dioxide (NO2). The tubes are installed outdoors for a period of two to four weeks and require no interim inspection or maintenance. They work by a process known as molecular diffusion. Each tube contains a gauze which has been treated with an absorbent chemical. The compounds in the air are at a higher concentration than those in the tube, so these compounds diffuse into the tube and collect on the absorbent. The rate at which the compounds move into the tube is called the uptake rate. The uptake rate is a known

Milieudefensie

Milieudefensie is a national environmental campaign group affiliated with the international Friends of the Earth movement. In 2013, it launched a programme in which members were asked to make monthly measurements of atmospheric NO2 values using Palmes tubes. Hundreds of people took up the challenge, forming sixty local groups responsible for a total of 101 monitoring sites throughout the Netherlands. Residents of the major cities (Amsterdam, Rotterdam and The Hague), who are perhaps most concerned about the local effects of air pollution, were particularly well represented. The monitoring sites were chosen by the participants themselves, with advice from Milieudefensie. Everyone contributed towards the costs of the Palmes tubes. The resultant data was made available to the relevant local authorities and supported a general discussion about air pollution and remedial action. A slightly different campaign was launched in 2015, the results of which were presented to several municipalities.

constant which is used in the analysis. The resulting concentrations are compared against those of the RIVM monitoring network. Measurements based on Palmes diffusions tubes that are used to calculate the annual average NO2 concentrations have a margin of error of between 15% and 25%. Although this is a relatively high figure, the method supports comparison with various other sources and therefore provides useful and useable information about air quality. The data thus derived can also be used to calibrate the computer models. Palmes tubes are a ‘passive’ monitoring resource. Ideally, they are used in combination with ‘active’ sensors which track variations over time.

Inexpensive gas sensors

Several reasonably priced gas sensors are now available. They include the Grove ‘MQ’ series which retail for under €10 (Further information: http://wiki.seeed.cc/Grove-Gas_Sensor-MQ2/).
The disadvantage of these units is that they are designed to detect various substances and are not suitable for monitoring a single gas or over a longer period of time. On the other hand, they are fully compatible with the Arduino and the Raspberry Pi. See Chapter 5: Hardware. All required software can be downloaded from the internet at no charge.

More advanced sensors and systems

Alphasense, City Tech, Sensortech and Shinyei Several are among the many companies which offer more elaborate gas sensors that can be used to measure concentrations of NO2 and fine particulates. The sensors differ in terms of range, accuracy and sensitivity. The table below lists some of the more popular models. Further information can be found at: https://www.samenmetenaanluchtkwaliteit.nl/.

NO_2 measurement	• **Sensoric NO2 3E 50** (Citytech) • **MiCS-2710/2714** (SGX Sensortech) • **NO2-B43F** (Alphasense)	From 10 to 250 euros
Fine particulate -measurement (particle counters)	• **Shinyei PPD42NS** • **Sharp Gp2y1010au0f** • **Alphasense OPC-N2**	From 15 euros Several hundred euros

Complete kits and systems

Standalone sensors generally require users to read and record the output data themselves. For this reason, they are more suited to people with some technical aptitude. There are also complete kits and systems which are somewhat simpler to use. Some are based on a portable sensor, while others are intended for installation and use at a single, fixed location.

The Dylos air quality monitor (illustrated) is useful for measuring fine particulates both indoors and outdoors. It is a laser particle counter with two size ranges, a thirty-day memory and various conversion features. Information about these and other self-contained monitoring systems can be found at https://www.samenmetenaanluchtkwaliteit.nl

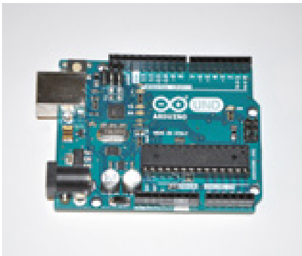
One interesting model is the Air Quality Egg (Version 2) which measures NO_2 and CO concentrations, temperature and relative humidity, and automatically uploads the monitoring data via the internet. See http://airqualityegg.com.

5. Hardware

A sensor produces only the raw data. To record, process and analyse that data, perhaps uploading it to a central database via the internet, you will also need some hardware. Two microcomputers are proving very popular for Citizen Science uses: Arduino and the Raspberry Pi. Many of the latest generation of measuring kits are based largely on one of these platforms. Individual sensors can easily be connected to these micro computers.

Arduino

The Arduino is an open source-computer platform. All hardware and most software are issued under a General Public Licence, which means that anyone can manufacture an Arduino board or distribute software without having to pay royalties. An Arduino can be programmed using any standard computer on which the operator creates a 'sketch' which is then uploaded to the Arduino. The programme language is very similar to C/C++with additional libraries for using the hardware. When the Arduino is switched on, it automatically starts whichever program has been loaded most



recently. A huge range of hardware and software is now available, with various providers offering 'all-in' packages. Grove markets an interface module (known as a 'shield') which allows up to 22 separate components to be linked to an Arduino board using standard connectors.

Raspberry Pi

The Raspberry Pi is based on ARM processors and was created primarily for use in education. The hardware supports various operating systems, loaded from a micro-SD card. Many of the most common operating systems for the Raspberry Pi are based on LINUX, although it will also run Chrome OS, RISC OS or Windows 3.1. Unlike the Arduino, which is basically a controller, the Raspberry Pi is therefore a computer in its own right.
The Raspberry Pi user has a wide range of hardware, software and peripherals to choose from. Most of the simple equipment that is available on the Arduino platform is also available for Raspberry Pi, including external interfaces which allow multiple sensors to be connected.

Connecting sensors

Various ready-made kits are available for both the Raspberry Pi and the Arduino, allowing one or gas sensors to be connected and their data read. The enthusiast need not even buy a kit but can make his own by following instructions on the internet. This may require some soldering in order to mount the connector pins. This is precision work; a mistake could cause problems at a later stage. Fortunately, both platforms have an extensive online support community.

AiREAS Eindhoven

AiREAS Eindhoven is a coalition of public sector authorities, private companies, research organizations and socially engaged citizens, all working together to create a cleaner city. Since late 2013, there has been a network of sensors, known as 'Airboxes', monitoring air quality in and around the city. It is the first urban sensor network in the Netherlands and, as far as can be ascertained, the most extensive in Europe.
The programme began with the design of the 'Innovative Air Quality Monitoring System (ILM). The Energy Research Centre of the Netherlands (ECN) upgraded existing sensors to make them suitable for routine monitoring. The result was a finely meshed network of sensors which measures atmospheric concentrations of fine particulates, ultrafine particles, NO_2 and ozone. Data is published on the AiREAS website (www.aireas.com) and can be used by anyone for any purpose. The online maps are updated hourly to show how concentrations are affected by the time of day and the weather. The use of new, high-quality and affordable technology has given the AiREAS network much valuable information about current air quality, thus supporting initiatives to improve health and safety for local residents and the business community. The data is used for various public information purposes as well as health research. One interesting initiative is an app which plots the 'healthiest' cycle route between two points. The healthiest route is not always the shortest route!

6. Networks

Monitoring the concentrations of certain substances in the air is an important step forwards for Citizen Science. However, the value of each individual measurement is limited. The measurements become much more useful when they are combined to form a significant body of data. It then becomes possible to compare readings between locations and over time. Patterns may then emerge which add even greater significance to the knowledge gained.

The most convenient way of sharing monitoring data is on the internet, preferably having first added metadata tags (information about the nature of the data). Some sensors have built-in internet connectivity based on WiFi or Bluetooth, while others collect data in log files which can then be uploaded to a central database.

There are several online data servers which are free to use. They include data.sparkfun.com and dweet.io. Once the data has been posted on the internet, it can be accessed and visualized on other sites, such as freeboard.io.

A more professional approach is currently being developed by Geonovum: the SOSPilot platform at sensors.geonovum.nl. The results of the RIVM National Air Quality Monitoring Programme are published on this website using the INSPIRE and Eionet standards.

iSPEX

iSPEX has been developed by a multidisciplinary team of scientists from RIVM, NOVA, SRON and the KNMI. It is a small device (a 'spectropolarimeter') which is mounted over the camera lens of an iPhone (version 4 or later), allowing the user to measure and record concentrations of atmospheric fine particulates. Data is automatically uploaded to a server where it is combined with data from other sources to produce maps and analyses. The data collected by iSPEX is comparable to that derived from professional monitoring instruments.

In a recent European project, nine thousand iSPEX attachments were issued to iPhone users in Athens, Barcelona, Belgrade, Berlin, Copenhagen, London, Manchester, Milan and Rome. They were invited to take measurements on all cloud-free days between 1 September and 15 October 2015. Users in the Netherlands who already had an iSPEX attachment were also able to take part.

Further information, including details of how you can become involved in a follow-up project, can be found at www.ispex.nl.

7. Getting started

This brochure provides all the (basic) information you need to begin monitoring air quality. Simply follow these steps:

Decide what you are going to measure and why

It is a good idea to think about what you wish to achieve. What is the purpose of your monitoring activities? From the health perspective, it is probably most useful to focus on nitrogen dioxide, (NO_2), fine particulate matter (PM_{10} & $PM_{2.5}$) and elemental carbon (EC). These pollutants are described in Chapter 3.

What level of quality do you wish to achieve?

When choosing your sensor(s) and monitoring method, it is important to consider the minimum 'resolution' that is needed to make your readings useful. This depends on several factors, including the 'typical' (average) concentration of the target substance in the atmosphere and the margin of tolerance of the monitoring equipment. See the table below.

What sensor is best for you?

To determine which sensor best suits your needs, you should first decide which substance(s) you want to monitor, why you wish to do so, and what computer hardware you will use to process or distribute your results. Other factors to be taken into consideration include scope, sensitivity, accuracy and, of course, price. The various types of sensors and systems are described in Chapter 4.

Substance	Typical concentrations	Permitted uncertainty of official monitoring equipment	Resolution (required smallest measurable difference)
NO_2	Hour: 5-200 µg/m^3 Year: 15-45 µg/m^3	7% 9%	5-20 µg/m^3
PM_{10}	Day: 5-70 µg/m^3	8-17%	~5-10 µg/m^3
$PM_{2,5}$	Day: 5-50 µg/m^3	11%	~5-10 µg/m^3
UFP	Hour: 5000 – 100000 particles/cm^3	Not applicable	~3000 particles/cm^3
EC	Jaar: 0.5 – 2.0 µg/m^3	Not applicable	0.25 µg/m^3

Where and when will you monitor?

Your results can vary significantly due to factors such as location and time. Concentrations close to a source are likely to be somewhat higher than the national average, for example. The choice of sensor location will also depend on whether you wish to measure specific 'at source' concentrations (e.g. alongside a busy road) or the average, ambient concentrations at some distance from a source. Populated areas are, in general, more interesting than those which are isolated or little used, since the health impact of emitted substances on humans is partly determined by the duration and degree of exposure.

Assuring the quality of data

It is important to check the validity of your data on a regular basis, and to ensure that your monitoring equipment is working as it should. Professional monitoring equipment is calibrated using samples of gases in known concentrations. The output of simple sensors should be regularly checked against that of more advanced equipment. One way of doing so is to take measurements as close as possible to an official monitoring station. You can then compare your readings against those published online.

What data collection method will you use?

Your data collection and analysis preferences will determine your choice of hardware. Both the Raspberry Pi and the Arduino platforms allow simple gas sensors to be connected. However, you should decide whether you wish to upload data to the internet on each occasion or would prefer to build a log file. The various options are described in Chapter 5.

Sharing knowledge

A single reading is of little scientific value. The more readings there are, the more useful they become. If there is a significant body of data, it becomes possible to compare and analyse the readings, and to identify any trends over time. New knowledge about local air pollution may then come to light, while the data can be used to support local and national policy decisions. You can upload your data to free servers such as data.sparkfun.com and dweet.io, thus making it available to others.

Screenshot app 'Mijn Luchtkwaliteit'

Also worth a look…

There are now various apps and websites which provide information about air quality. They include:

- **Mijn Luchtkwaliteit:** a free smartphone app (available for iOS or Android) which offers current air quality information and a 48-hour forecast. Users can set a warning level and receive an automated message if concentrations exceed that level. In addition to the most recent monitoring readings, the app visualises the concentrations of various substances by means of a map of the Netherlands.
- **Atlas Leefomgeving (www.atlasleefomgeving.nl):** a mainly Dutch website offering information about the environment in the Netherlands, with a focus on health aspects. It includes interactive maps showing both current concentrations and yearly average concentrations of the various atmospheric pollutants.
- **Luchtmeetnet.nl:** a website which publishes air quality readings, visualized in the form of maps. Data is derived from the official monitoring networks of RIVM, GGD Amsterdam, Rijnmond Environmental Health Department, the Province of Limburg and the Midden-en-West Brabant Environmental Health Department.
- On February 13, 2017 the Centre for Environmental Quality of the Dutch National Institute for Public Health and the Environment hosted the meeting "Status of Air Quality Sensors and their use in (official) monitoring strategies". With around 60 participants from 15 EU countries, from EPA's, knowledge institutes and commercial institutes, it is clear that there is much interest in the subject. A summary of the meeting (in English), including pdf's of all presentations can be found at the website https://www.samenmetenaanluchtkwaliteit.nl/minutes-intl-meeting-air-quality-sensors-13-2-2017.

8. The future of Citizen Science

Short term

Monitoring technology based on small, relatively inexpensive sensors is still in its infancy, although rapid progress is being made. The sensors currently available remain sensitive to factors such as temperature, relative humidity and the presence of gases other than that being monitored. Their results are therefore neither consistent nor completely reliable. Within a few years, however, technology is likely to advance to the stage that readings made by members of the public are more than adequate to support scientific aims and policy formulation.

For local authorities, it will be interesting to examine the concerns that people have about air quality, and to explore ways in which new technology can address those concerns. Compact sensors and data derived from Citizen Science will enhance their knowledge of local air quality issues. It will become possible to assess the effects of policy measures at specific locations and at specific times.
The new technology and more detailed data will support policy formulation, and may indeed prompt policy reform. In any event, we shall all have a far better understanding of the quality of our human environment.

Longer term

Citizen Science is seen as an intrinsic part of the modern 'Smart City', a setting in which engaged individuals take an active part in promoting social and societal development. Frank Kresin, Former Research Director with the Amsterdam-based Waag Society (presently at university of Twente), sees a clear evolution in the Smart City and the role of its residents.
Smart City 1.0: this first generation Smart City attempts to provide its residents with all possible amenities, but continues to regard them exclusively as consumers. This Smart City is a machine which has to be optimized, regardless of limited space and equally limited understanding of organizational complexity.
Smart City 2.0: the second and subsequent generations of the Smart City will see technology taking an ever more prominent role in resolving urban issues. It will bring new insights and will almost certainly create a healthier human environment, coupled with greater efficiency and cost reductions.

Sustainable innovation demands the active participation of engaged citizens. They will be responsible for the new insights, and they will be willing and able to pursue the adoption of promising solutions. Their voice must be heard. The Smart City 2.0 must therefore focus on bottom-up innovation, on strengthening connections and on embracing the resultant 'creative friction'.

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RIVM
National Institute for Public Health and the Environment
Postbus 1 | 3720 BA Bilthoven
www.rivm.nl

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