Expanding perspectives on Air Pollution in Cities - using data to identify new avenues for city planning

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Abstract

The science of air quality is gaining a lot of new grounds in recent years due to new advances in sensors, data collection, and computing technologies. New sensors are moved out the laboratories and on to the streets, where they are able in measuring at ultrafine and molecule scales. These data are propelled into health analyses documenting new correlation to a wide array of physical and neurological diseases.

The density in cities of human activity and the canyons between the buildings exacerbate the impacts of air pollution on to humans. With increased urbanisation and increased densification of existing cities this is a global challenge cities face.

In Copenhagen, a collaboration between Google and Copenhagen Solutions Lab , an innovation arm inside the municipality, is using a StreetView car to investigate the air quality of every street in order to generate a data based foundation to find solutions to cities' challenges.

1 | Introduction - the evidence is building up

The United Nations' World Health Organisation places air pollution as the 3rd global killer shortening the average human life span with 22 months. Even in a clean city like Copenhagen air pollution is taking away 1 year of average life expectancy when contrasted to the average of Denmark.

The reduction in life expectancy from air pollution comes in the form of cancer, cardio-arrests, and strokes. New sensors facilitate new avenues of research and documentation of new insights to pollution effects on human health. NO2 impacts the metabolism of lipids and antioxidants; laboratory results show a toxicological relation between ultrafine particles and oxidative stress - a disorder that weakens the natural redox processes of the body - which in turn is linked to an array of neurological disorders like ADHD, autism, dementia, Parkinson's, depressions and more.[1] Many of these disorders that at present are categorised as non-communicable, inborn and genetic, but have been shown to have an urban disposition.[2]

[1] For an overview, see Schraufnagel, Dean E. et al (2018): *Air Pollution and Noncommunicable Diseases A Review by the Forum of International Respiratory Societies' Environmental Committee, Part 1: The Damaging Effects of Air Pollution,* https://journal.chestnet.org/article/S0012-3692(18)32723-5/fulltext#

[2] Ole Raaschau Nielsen et al (2018): *Air Pollution and Autism in Denmark*, Environmental Epidemiology 2:e028,

The wider recognition of air pollution as 'the new tobacco'[3] the correlation to non-communicable diseases is rising: socioeconomic analyses tend to increase the savings on health expenditures due to improved documentation[4], and a coroner's verdict concluded the cause of death of the 9 year old girl Ella Kissi-Debrah to be air pollution marks a watershed court case in Britain.[5] It marks very clear change to the prevalent perspective of causing premature deaths to already old people to a perspective, where impacts are lifelong and beginning at birth.[6]

2 | City Challenges

Cities will struggle to minimise air pollution. The main source of ambient air pollution is traffic. Cities are centres of many different activities, economic, cultural, social, all of which are hinged on transport needs. A foundational dilemma is between how to secure economic activity and employment, while reducing air pollution. Here, things are in motion. High profiled cities like Paris, Milan, and Barcelona are in similar ways tackling situations where congestion, air pollution arebeing pushed back in favour of revitalised locale neighbourhoods with much less commuting.

Critics argue against the Parisien 15 minute city or Barcelona's Superblocks as urban elites' utopias, only fit for a narrow homogenous segment of resourceful and likeminded professionals, However, not fit for the people who rely on cars because of couples' different job geography, or disabilities, or small scaled production facilites in need of heavy trucks.

In honest truth it is fair to say that city planners have very few established tools to bring about the transition to a fossil free, cleaner air future city. The Parisien 15 minute city or Barcelona's Superblocks are best viewed as full-scale experiments fuelled by situations where the urban neighbourhoods have been squeezed by congestion, parked cars, by air and noise pollution to a degree where enough is simply enough.

And it is from this starting point the air quality project in Copenhagen takes off - with the ambition to bridge the gap between urban economic activity and a healthy city. It is an open-ended effort, done together with external partners (Google, Gehl Architects, University of Utrecht, University of Aarhus, Backscatter, Studio Profondo) and financed primarily by external funds (Bernard van Leer Foundation, ICLEI Action Fund). This constellation enables collaboration between highly competent innovation capacities, while maintaining an arms' length to political decision-making, who are free to build back better without departmental bias.

[3] Used in WHO communication. WHO puts air pollution as the 3rd highest cause of death globally: https://www.who.int/airpollution/events/conference/en/

[4] Sander, de Bruyn et al: *Health costs of air pollution in European cities and the linkage with transport,* CE Delft, https://www.cedelft.eu/en/publications/download/2976

[5] https://www.theguardian.com/environment/2020/dec/16/air-pollution-verdict-shines-political-light-uk-invisible-killer-ella-kissi-debrah

[6] Health Effects Institute. (2020) *State of Global Air 2020. Special Report*. Boston, MA:Health Effects Institute.https://www.stateofglobalair.org/sites/default/files/documents/2020-10/soga-2020-report-10-26_0.pdf

Project Airview: Street by street measurements in Copenhagen

In 2017 Google approached City of Copenhagen with vision for a collaboration to measure air quality using the Google Streetview car as a mobile sensor station. Copenhagen Solutions Lab had already tested new stationary sensors and came as an opportunity to provide a city-wide perspective on the air quality in Copenhagen. The partners settled to measure with a focus on the pollution emitted within the city limits rather than the pollution coming from outside sources, i.e. to measure ultrafine particles, black carbon, NO2 but also the larger particles (PM2.5 adn PM10) for reference.

The project has logged 6 million measurements, each with the five pollutants, time stamp, and a gps location. The equipment logs one measurement per second and a car speed of 50 km/h this equals a data point for every 14 meter of driving. The campaign has made 6 rounds of driving on every street in Copenhagen. The major roads have been driven more.

In October 2019 the team published a preliminary map of the air quality in Copenhagen as half of the data collection had been concluded. The data for the published map is the measured data only and has not been processed to represent air pollution in a static way like a map. The data collected have been collected from November 2018 until September 2019. While the overall conclusions most likely will remain the same, specific values for each street will change in the final map. Therefore, the map was published without detailed values but only broad colour indications.

In the spring of 2021 the final map will be published, along with the data set, corrected for technical errors. The data set will be shared openly and everyone will be able to access the data.

1.1. The Complex World of Air Pollution and Measurements

Air quality in cities depends on a variety of factors. One of the most important is the wind. The wind carries particles and gasses over city boundaries from faraway sources and mix it with local sources. Wind speed determines how the pollution dilutes. Fixed structures like buildings, squares, trees etc. all have influence on local wind speed, turbulence, temperature and other factors that in turn influence the measurements.

Using a car with equipment capable of logging one measurement per second provides a very granular spatial data set. A speed of 50 km/h equals a measurement for every 14 meter of driving. In terms of data, the project adds two new variables, time and place to measuring air quality. The addition provides the ability to zoom in on where and when people are exposed to pollution. This provides a number of interesting perspectives:

Firstly, it provides a focus on human activities in the city causing the pollution. With sensors picking up the pollution created in the city the insights from the data can specify the changes in behaviour need to improve the air quality. Choosing one route over another can means a large difference in exposure if taken everyday. Taking an electric train will mean much less exposure than sitting in a queue amidst plumes on the motorway.

Secondly, the granularity of the data reveals the interplay of physical installations and consequences for air quality. In narrow streets pollution builds up, in others the prevalent wind direction will dilute the plumes. Traffic lights cause stops and accelerations, some bus stops block the street

for cars, others let them pass without stopping. Connecting traffic lights to manage where queuing is happening can lower the exposure of humans, but can also be problematic if it is in front a school etc.

3 | Identifying, Enriching, Experimenting to Bring about New Solutions

In October 2019 the mayors of the C40 cities met in Copenhagen and signed a declaration to combat air pollution. As part of this declaration cities sign to put in place monitoring schemes and adhere to the guidelines of WHO for air quality. At her speech deputy mayor Ninna Hedeager Olsen disclosed an intermediary data-only map for air pollution in Copenhagen. The map was based upon data collected half way of the project.

From the map one can identify the major inroads as the most polluted areas, but also the city center as an area with relatively more air pollution than other areas. Also, it is evident that for the ultrafine particles, NO2, and the black carbon particles the measurements reveal a quiet localised dynamic where pollution levels drop markedly between short distances. Streets with little traffic show much lower numbers than their adjoining busy streets. This insight is essential to adding new ways for planning design to reduce *human exposure* to pollution.

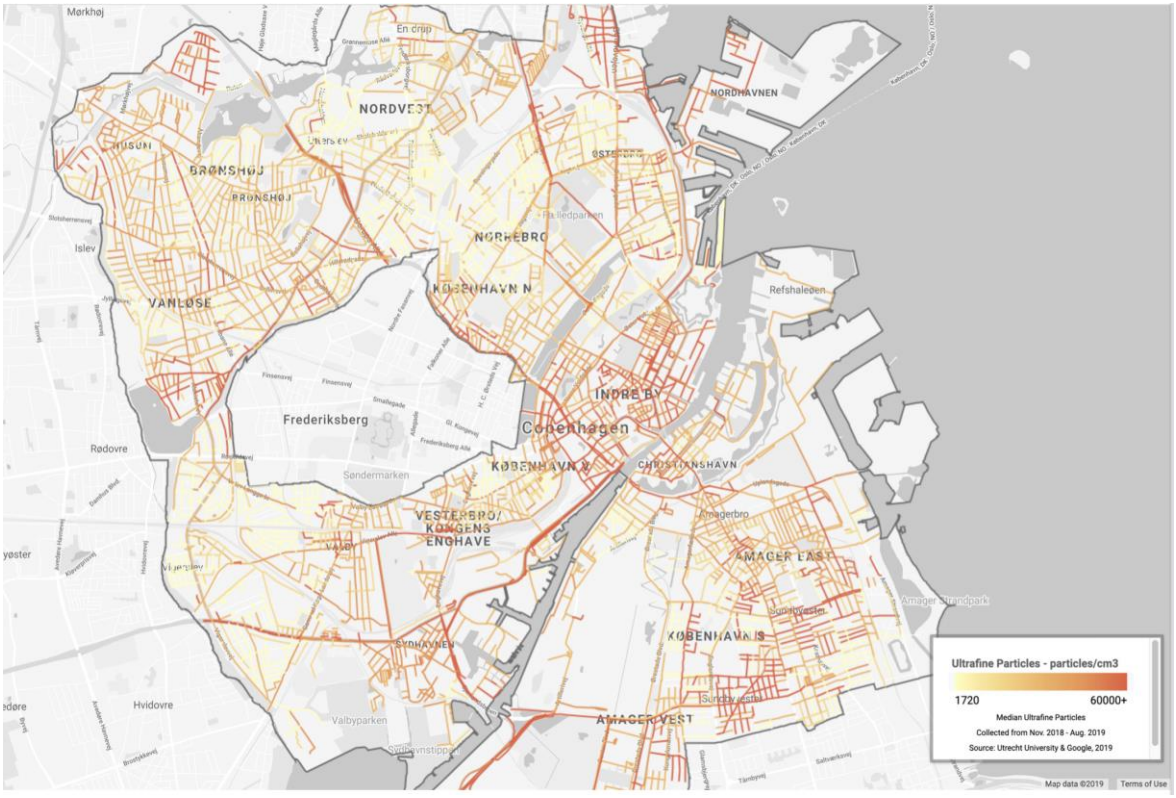

Figure 1: The preliminary map for ultrafine particles in Copenhagen with the visible inroads and city centre as most polluted areas. A adjustable version of the map can be found here: https://insights.sustainability.google/labs/airquality and choose Copenhagen from the dropdown menu.

To explore the avenues of a urban design as a framework for reducing exposure a collaboration with Gehl Architects was forged. Gehl Architects is a well known urban design agency based in Co-

penhagen with a strong focus and expertise on making liveable cities. They were added to the consortium with a question on how city planning should change when including air pollution. The first sketches of solutions were presented in a workshop at the C40 Summit.[7]

One ambition was to draw up a set of guidelines that included air quality as a pillar in city planning that could serve as principles for city planners based upon data and scientific insights. Also, the work focused on making better cities for people rather than reducing air pollution from reducing the source of pollution, i.e. in most cities: traffic. A key concept became exposure to utilise the dynamics of the air pollution created within the city limits. Exposure is combination of the level of air pollution and the duration of time individuals spend in the pollution. To include a socioeconomic perspective the number of people is added.

The first project phase focused on children under 6 years of age in Vesterbro, a part of Copenhagen. Children have a special vulnerability to air pollution as their body and neurosystems are under construction and as they breathe at a much higher rate than adults their relative exposure is up to 4 times higher. Vesterbro is one of the districts in Copenhagen with the highest concentrations of children and care institutions. Also, it is a neighbourhood where air pollution is higher than expected, in comparison to volume of traffic.

A second phase took the concept to the City Centre and to Sundby at Amager to verify the concept. The third phase has just started and will implement and test solutions.

1.2. Redesigning street hierarchies for air quality

With Gehl's public life public space methodology of observing how people act in the city, we logged how, when and what children were doing in the district. These insights were coupled with data for air pollution and time of day. Many were transported in the morning rush hour and again in the afternoon rush hour when pollution levels were high. Interviews with parents and caregivers were added to learn why this was so.

Of course, this relates to everyday activity, going to work and bring the children to an institution before and after. Often a very local activity, determined on the parent's need for transport. A first insight was a need for a 'safe route street hierarchy' that would enable cyclists and pedestrians to travel locally and between districts of the city without being exposed to the high level of air pollution. Many of Copenhagen's bike lanes are constructed next to the main arteries leaving cyclists less than two meters from the tailpipes of traffic. An air quality included street hierarchy focus on how safe routes can be connected by adding missing links, and thereby *inviting* people to take the fastest and least polluted route through the district and further through to the city.[8]

[7] https://cphsolutionslab.dk/en/projekter/themes/air/copenhagen-solutions-lab-indgar-i-et-nyt-projekt-om-luft-forurening (in Danish)
[8] https://gehlpeople.com/projects/air-quality-copenhagen/

Figure 2: An air quality included street hierarchy focus on how safe routes can be connected by adding missing links, and thereby *inviting* people to take the fastest and least polluted route through the district and further through to the city

1.3. Adding distance to pollution where people are

The granularity of the measurements allows for enriching the data set. In the perspective of exposure the situations where humans spend most time are the important ones to reduce. Zooming through traffic in the morning rush hour might give a short high volumes intake, whereas other activities have other patterns of exposure.

At Sundbyøster Plads the existing design of the square lead people to spend time in the areas with the most pollution. A playground area (marked as green below) is placed next to the main artery, Amagerbrogade. The playground is also used by the school opposite Smyrnasvej. The blue dots mark, in the figure below, where people are occupied in activities, that is where stay for a longer time. A design that includes air quality could have invited people to stay at the other end of the square by placing the playground furthest from Amagerbrogade.

Since it is not easy to change the layout of cities the project investigates the possibility to protect or shield people from the pollution rather than inviting people to spend time elsewhere. Istedgade is a typical shopping street with curb side cafés and an important social axis in the district. The width of the street and course given by the buildings, but also reservations to the overall possibilities for people to get in and out of the district are important and can make it difficult to apply improvements.

Gehl's Architects registration of where people stay at Sundbyøster Plads. A playground is located closest to the main road rather than towards the less trafficked side.

Looking for tools to address this problem existing knowledge really does not give solid answers. Some studies suggest plants and greening can reduce the pollution, others point to trees as reducing wind speeds and thereby holding on to pollution. While there is documentation that distance to the source reduce exposure there is little consensus on how much at urban scale. We hope to be able to enlighten this by using the full data set as it is published.

4 | End remarks

Using planning design is an important tool but also comes with its natural limitations. The first option to reduce air pollution is at the source, and many actions are being taken; electrifying transport is being applied at increasing pace, but EVs also emit particles from tyres and breaks, so although better the problem will not disappear entirely. And we cannot change cities every time we learn new of challenges. But we can apply the knowledge when changes are being made to urban structures anyway.

Urban design and planning are also city tools, in contrast to others that are applied at national level. Air pollution is from a human exposure perspective a predominantly urban challenge from the density of activity and buildings that inhibits its dilution. In Denmark, the definition of local environmental zones is a national competence with little influence from municipality level. There lies a potential fundamental conflict between viewing cities as regional centres of economic activity or as local places for living people.

COVID-19 and the peaked acceleration of digitising of work flows along with the increased focus on climate action, can potentially change the balance of cities as local or regional centres of activity. The need for coming to town will decrease and be detached from economic activity. How this will change cities is still a big unknown, but the result will be reflected in the design of urban streets. The projects described here are trying to invoke urban design principles to enable citizens to live in cities without severe implications to health