Smart Control of Air Pollution

Policy Briefs from the **iSCAPE** project funded by the European Union's Horizon 2020 Research and Innovation Programme

Introducing infrastructural passive control systems in cities

Contents

Key Take-Aways

A step by step process for city governments wanting to adopt infrastructural solutions for air pollution prevention and control (such as low boundary walls and photocatalytic coating) in their local environments.

For many years, European regulatory authorities have based their approach towards improving air quality on selective emission reduction strategies. These have sometimes achieved their goals, though at the cost of shifting the challenge to other areas or technological sectors.

Moreover, during the past ten years, the evidence has become widespread that achieving further emission reductions is practically difficult, particularly in our cities. Therefore, it is now inevitable (and also highly recommended) to examine the potential benefits and implementation conditions of passive control systems.

Among those, a prominent role can be played by physical infrastructures such as low boundary walls or noise barriers and photo-catalytic coatings (in road tiles or walls), and more generally by intelligent urban design, acting on the settlement structure, road geometry, traffic lights and other pollution generating situations. The gains in terms of urban air quality can derive either from a lower presence of primary air pollutants or globally improved urban climate parameters.

This Policy Brief provides an **overview of the strengths and weaknesses of both new investment strategies and low-cost retrofits of existing infrastructural passive control systems.** Since all these actions and structures generate long-term effects, the return on investment can be high and the cost comparable with that of regulation.

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Recommendations and guidance are also given on the handling of these passive interventions.

"Landscaping for climate is the next big thing in our City"

A member of one of the city pilots.

Background

A number of **solid barriers** have been identified and investigated as passive control systems that are likely to improve air quality in cities. These include noise barriers, low boundary walls and (although in a temporary manner) parked cars themselves.

A **noise barrier** (Figure 1) is a permanent installation, often located along a high-speed highway. Its height is typically in excess of 4-5 meters and its positioning is not necessarily related to the additional goal of influencing air flow and pollutant dispersion. In fact, several investigations carried out in relation with particulate matter (PM) and carbon monoxide (CO) have demonstrated that the introduction of a noise barrier can reduce air pollutant concentrations behind the barrier by approximately 15%, but at times reaching 50% of pre-intervention levels. In some cases, the downwind location may be a densely populated area, therefore implementing this type of barrier may help improve air quality conditions for urban inhabitants. However, it is also true that a noise barrier traps the pollutants on the upwind side of the structure and that may lead to higher concentrations in this location, unless the passing vehicles create some turbulence that increases air mixing and dilution. Finally, the potential for solid noise barriers to influence pollutant dispersion was found to be impacted by the geometry and layout of the noise barrier. This means that a standard solution providing simultaneous air and noise quality benefits has yet to be identified.

Figure 1: Noise barrier adjacent to a highway.

A **low boundary wall** can be considered as a scaled down alternative to a noise barrier (its height being typically of 1-2 meters or less) that is sometimes installed on low speed roadways and boardwalks. Due to the low number of working installations in cities, evidence of their influence on air flow and pollutant dispersion mostly derives from simulation studies. These are, however, quite consistent in highlighting their benefits, particularly on air quality on the sidewalks in urban street canyons, as exemplified by Figure 2 below.

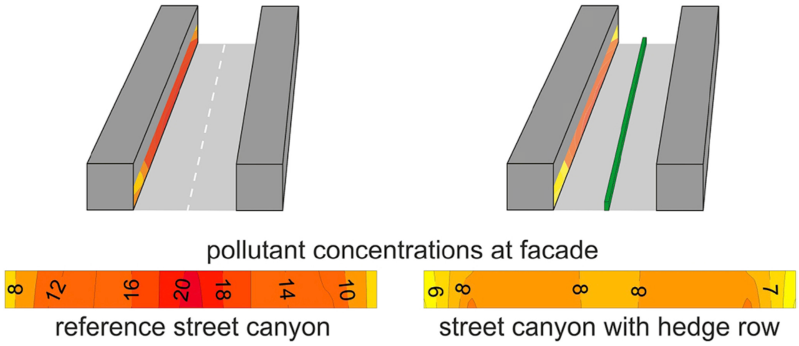

Figure 2: Comparison of pollution concentration at walls inside street canyon with and without hedge row. (Source: Gromke, C., Jamarkattel, N. and Ruck, B., 2016. Influence of roadside hedgerows on air quality in urban street canyons. Atmospheric Environment, 139, 75-86)

Low boundary walls seem to act as a baffle and alter air flow patterns at street level, reducing the impact of pollutants such as benzene, CO, PM2.5 or NOx. Similar to noise barriers, these findings suggest that effectiveness is dependent on varying factors, such as the street canyon geometry; the height, location and configuration of the barrier; wind conditions and the local air turbulence and dispersion created by the passing vehicles. However, further studies are required to get to a complete definition of observed features in a broad range of urban climatic and built environmental conditions. Additionally, a confined street canyon study needs to be expanded to a city-scale, as the frequency and variation of road characteristics and intersections also matter for a complete assessment of benefits and costs.

Finally, **photocatalytic coatings** are conceptually based on the process of photocatalysis, driven by sunlight and leading to transformations in the molecular structure of the contaminated surface of e.g. road pavements and liberating more neutral and volatile compounds into the surrounding atmosphere (see Figure 3).

Figure 3: Air purifying pavement to reduce NOx concentration in Hengelo, Netherlands. (Source: Ballari, M.M. and Brouwers, H.J.H., 2013. Full scale demonstration of air-purifying pavement. Journal of Hazardous Materials, 254-255, 406-414)

Despite the extensive laboratory research on photocatalytic oxidation technology for the removal of organic and inorganic compounds from different kinds of material, limited field work had been carried out before the iSCAPE project started. Known technical problems are mostly related to the removal efficiencies of materials and how these might alternatively behave in real life testing environments. The iSCAPE pilot in Lazzaretto (IT) (see Figure 4) allowed to provide an evidence-based assessment of the performances of photocatalytic coatings in real-life setting, thus filling the gap in the current state of the art. The assessment combined a wide range of measurements with modelling techniques in order to provide a solid evaluation of the positive impact of the coating on the pollution in a street canyon environment. It highlighted also some limitations and scope for future work. For instance, the coatings need to demonstrate a stable photocatalytic activity for a long period of time considering the normal usage period of construction materials. Another known technical limitation is the low reachability of gaseous contaminants to the photocatalyst surface under the condition of low airflow rates. Future work should priorities the development of new photocatalysts that can demonstrate high adsorption performance in the presence of various VOCs (Volatile Organic Compounds) and discover new compositions of products that are less influenced by moisture levels, generate fewer or no by-products, and show an enhanced ability of trapping photons from ultraviolet (UV) to sunlight spectrum. The latter aspect also points at the differential outcomes of experimental field installations in Northern and Southern European areas, exposed to normal sunlight for quite diverse average time spans.

Figure 4: Photocatalytic coating pilot in Lazzaretto (IT).

Project Evidence

The iSCAPE project approached the issue of adopting passive control systems and especially built/grey infrastructures by starting with the creation of **city profiles**, including compact presentations of information on air quality parameters and other environmental conditions throughout the six pilot cities (Bologna-IT, Bottrop-DE, Dublin-IE, Guildford-UK, Hasselt-BE and Vantaa-FI). A distinctive feature of this approach is that information was displayed in a clear, easily understandable and consistent way that allowed immediate comparisons between the different cases. Additionally, to overcome the limitations of environmental-only information, a number of **spatial indicators** were added to each profile in order to gain an adequate overview of the contextual elements and factors - such as the state of road network and public transport system, the localisation of industry, education and trade hubs and mobility attractors, as well as the existing green and "blue" spaces - which may influence air quality in several concurrent ways. The chosen spatial indicators were meant to closely reflect the cities' specific characteristics and help anticipate how local conditions foster air pollution and urban heat. However, these indicators were always expressed in absolute numbers, needing some benchmark value to be properly understood. For example, urban green areas cover more than 12% of the total area of Dublin, but in comparison with the other iSCAPE cities, Dublin's share of green and blue spaces is quite low.

Based on gathered information, also complemented by **simulations regarding the impact of passive control systems** on air pollution and climate change mitigation, a number of test sites have been identified in each city, where the deployment of built /grey infrastructure were realised (for instance: street canyons apt for the installation of low boundary walls).

In retrospect, the following lessons and recommendations can be drawn from the project's experience.

Low boundary walls:

- In order to achieve maximum efficiency in reducing air pollution for pedestrians, these should be as continuous as possible;
- Gaps must be provided at the junctions of roads, near bus stops, buildings and schools, to ensure accessibility;
- Their height should be within a certain range (0.5-1m) to ensure visibility of drivers, cyclists and pedestrians;
- In certain circumstances it might be necessary to remove them temporarily to increase accessibility inside the canyon. Hence the low boundary walls should be made of materials that are light-weight and easily transferable, such as tarpaulin sheets. As the strength of those materials is lower compared to concrete walls, they must be properly installed in order not to be easily displaced due to factors such as strong winds;
- While low boundary walls can reduce air pollution at certain sections of the road and footpath, they can have a reverse effect in some other sections of the street canyon. Their exact location should therefore be selected in such a way that air pollution reduces in front of important buildings such as schools and offices, even at the cost of an air pollution increase in other parts of the street.

Photocatalytic coatings:

- Available products' performance differs with the nature of the pollutant degraded, for instance NOx or VOC;

- In general, products greatly differ on their durability with time, which can be assessed with prior mechanical resistance and freeze-thaw experiments. Available products differ also for the level of TiO2 coating adhesion on concrete tiles. Because of the surface nature of the photo-oxidation reactions of NO, TiO2 must present on the exposed surface to be effective on air pollutants;
- The chosen photocatalytic product must be applicable to concrete structures (e.g. walls and pavements) in a low-cost manner such as by spraying;
- Different deposition methods such as screen printing, ink-jet printing, roller printing, dip coating, liquid-phase coating offer various advantages and disadvantages;
- Not all commercially available products are equally photoactive/responsive to visible/UV light.

Concerning the **impact of meteorological conditions and building/street layout** on the site of interest:

- The strongest reductions are observed with the maximum UV sunlight, around noon. Sites often affected by cloudy conditions are not appropriate for interventions with photocatalytic coatings;
- Although summer is the season with the longest sunshine duration and therefore greater availability of UV sunlight for activation of photocatalysis, the presence of some shadows at noon may limit the reduction; reductions may be larger in wintertime sunny days, around noon;
- The largest reductions are observed with wind perpendicular to the painted wall;
- Finally, the following recommendations are related to the **urban geometry** and in particular to the ratio between building height (H) and width (W) of the street canyon:
  - With a ratio H/W ≥ 2 (deep or narrow street canyons) photocatalytic coating is NOT recommended due to its limited air pollution reduction potential;
  - With a ratio 0.5 < H/W < 2 (moderately deep or nearly regular, e.g. w~=h, street canyons) photocatalytic coating is recommended but has limited activation potential;
  - With a ratio H/W ≤ 0.5 (shallow or wide street canyons) photocatalytic coating is recommended and has the greatest potential.

Keywords to remember

Air pollution:

Harmful emissions of particulate matter (PM), nitrogen oxides (NO_x) carbon monoxide (CO) and other volatile organic compounds (VOCs). Air pollution is particularly harmful for children, senior citizens and people with breathing related health issues.

Built (or Grey) Infrastructures:

As distinct from green infrastructures, they include noise barriers, low boundary walls, photocatalytic coatings, roundabout intersections and other road geometry interventions.

Passive Control Systems:

green and built urban infrastructure for air quality and/or urban thermal comfort improvement, including e.g. low boundary walls, trees and hedges, green walls and roofs, photocatalytic coatings, green urban spaces and road geometry interventions.

Urban Climate:

The environmental conditions of cities and towns, differing from those in neighboring rural areas, as a result of urban development.

Read More

The content presented herein is based on the following key project deliverables: **D1.2** 'Guidelines to Promote Passive Methods for Improving Urban Air Quality in Climate Change Scenarios' (October 2018), **D3.8** 'Report on Deployment of Neighbourhood Level Interventions' (February 2019), **D3.9** 'Report on Deployment of Urban Interventions' (July 2019) and **D7.2** 'Generalised recommendations regarding passive control systems for improved air quality and climate change mitigation' (November 2019). The underlying evidence refers to the six iSCAPE pilots run in the cities of Bologna-IT, Bottrop-DE, Dublin-IE, Guildford-UK, Hasselt-BE and Vantaa-FI.

All reports are available on the iSCAPE project website: www.iscapeproject.eu

Impressum

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The iSCAPE project

iSCAPE aimed to reduce urban air pollution and the negative impacts of climate change by leveraging sustainable passive control systems, behavioural change initiatives and the Living Lab approach.

For more information: www.iscapeproject.eu.

iSCAPE partners:

University College Dublin	
University of Bologna	
University of Surrey	
Finnish Meteorological Institute	
Hasselt University	
TU Dortmund University	
JRC - Joint Research Centre - European Commission - Institute for Environment & Sustainability	
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Smart Control of Air Pollution - Policy Briefs

The Smart Control of Air Pollution - Policy Briefs series summarises key outcomes of the iSCAPE project with a clear policy orientation, to provide practical information to EU local decision-makers and other urban stakeholders. They cover the following topics:

No. 1 **Living Labs for air pollution control and prevention**

No. 2 **iSCAPE manifesto for citizen engagement in science and policy**

No. 3 **Effectiveness of travel behavioural change interventions**

No. 4 **Simulating change in urban air quality and climate conditions**

No. 5 **Urban strategies and interventions for planning healthier cities**

No. 6 **Improving air quality and climate with green infrastructure**

No. 7 **Air quality sensing and real time reporting in cities**

No. 8 **Introducing infrastructural passive control systems in cities**

No. 9 **Citizen Science: a collaborative approach to air pollution control**