19th International Conference on
Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes
3-6 June 2019, Bruges, Belgium

H2020 CLAIRCITY PROJECT: ASSESSMENT OF AIR QUALITY IMPACTS FOR BRISTOL CITY COUNCIL

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Abstract: ClairCity is a European project funded by the European Union's Horizon 2020 research and innovation programme. The project applies an innovative quantification framework developed to assess environmental, health and economic impacts. The quantification framework was applied and calibrated for the baseline situation of the ClairCity pilot case study – a UK city. The second-generation Gaussian model URBAIR was set-up to simulate NO_2 and particulate matter concentrations.
The simulation results point out several exceedances of NO_2 concentrations, while the PM10 and PM2.5 concentrations are lower than the EU annual legal limit values all over the study area.
The ClairCity impact assessment framework was then applied to evaluate the impact of scenarios considering 3 time horizons: 2025, 2035 and 2050. The scenarios consist of the Business As Usual (BAU) scenario and 3 additional scenarios translating the expectations of citizens and local experts based on data collected through engagement process. The most ambitious scenario – Scenario 3 – favours banning and charging vehicles for entry into the city, the subsidization of public transport and using area planning actively to minimize the length of commuting and the necessity for travel. This scenario also focus on households energy efficiency and banning solid fuels for new households. The numerical results point out a maximum decrease of 62% of NO_2 concentrations for the most ambitious scenario in 2050, compared with a decrease of 37% in the BAU scenario in 2025.

Key words: *H2020 programme, ClairCity, air pollution reduction, citizens engagement, European cities, urban areas*

INTRODUCTION

European Union has made significant progress over the last decades towards a clean air. This progress was mainly achieved due to the implementation of effective policies of air quality management, the development of emission inventories for all the member states, the development and implementation of a common and harmonized framework for monitoring and modelling air quality, which allow a deep knowledge of the European air quality. Despite all the progress, European countries are still facing acute air pollution episodes. The overall policies of air quality management implemented up to now tend to be focused on emission reductions through the technological transformation, e.g. the technological revolution in the transport sector has led to progressive emission reductions of distinct air pollutants. However, there is still a key missing factor in the way cities and societies organized themselves and work: citizens at the heart not only the problem, but also the solution, focusing on their behaviour, activities and practices (Barnes *et al.* (2018), Chatterton and Wilson (2014)).

Therefore, the ClairCity (Citizen-led air pollution reduction in cities) project aims to improve future air quality and carbon policies in European cities by initiating new modes of engaging citizens, stakeholders and policy makers. ClairCity is putting citizens and their behaviour, activities and practices at the centre of air pollution and carbon management. The project is applying the latest advances in social sciences to carbon emissions and air pollution sources and their consequences for human health, linking sources of pollution with citizens' behaviour, activities and choices (e.g. travel to work, shopping, and leisure).

The ClairCity emission database includes point sources with the emission rates of the large industry sources, the line sources with the road traffic emissions and the area sources covering the residential, commercial and industrial emissions from the IRCI module. The database is built from distinct emission sectors, in line with statistics by sector, by time of day, establishing the link with citizen's behaviour. This database is physically stored into the ClairCity Data Portal and will be fully public available by the end of the project.

ClairCity uses six cities/ regions – Bristol in the UK, Amsterdam in the Netherlands, Ljubljana in Slovenia, Sosnowiec in Poland, Aveiro Region in Portugal, and Liguria Region in Italy. The pilot case study is the city of Bristol in South West England. The key pollutants of interest are NO_2 and particulate matter, where other air pollutants are not as significant for the current issue for the city. ClairCity focuses particularly on the transport and energy related behaviour of Bristol citizens and its contribution to air pollution and carbon emissions.

To understand the impact of the measures citizens and stakeholders put forward, the quantification framework assess the impact of the designed policies on emissions, air quality, human health and related costs. The estimation of future emissions evolves in a do-nothing scenario and model the resulting air quality. The business-as-usual "BAU" scenario aims to capture the changes on the air quality if no further measures are taken in the expected technological and behavioural changes. The BAU scenario reflects the normal trend without any policy or other interventions beyond the measures already established. In the other hand, the SDW scenarios translate the vision and expectations of citizens and local experts based on data collated through engagement processes (e.g. Stakeholders Dialogue Workshop, Delphi, ClairCity Skylines Game and Mutual Learning Workshop) plus evidence from the baseline policy assessment of Bristol. These scenarios will be used to support and inform the development of city policy packages out to 2050.

The air quality assessment was performed covering distinct spatial scales: the WRF-CAMx modelling system was applied to European domain using a horizontal grid resolution of 0.25 degrees, and then to the regional domain covering the urban area of Bristol using as horizontal resolution 0.05 degrees, both in an hourly basis. The Gaussian model URBAIR was then setup and run at urban scale for the computational domain over the urban area of Bristol of 20 km x 20 km with a horizontal grid resolution of 200 m x 200 m. The baseline simulations were performed using as input data the meteorological vertical profiles provided by the WRF model. The air quality simulations were performed for the full-year in an hourly basis. The concentrations of NO_2, PM10 and PM2.5 were simulated using the emission rates available on the ClairCity emission database. The air quality is assessed for the current situation through modelling tools, evolving towards the comparison of the simulation outputs with observations.

AIR QUALITY AND EXPOSURE

The application of the quantification framework encompassed the simulation of the industrial, residential and commercial, and transport emission sectors. The assessment of impacts was performed in terms of air quality and population exposure focus on NO_2, PM10 and PM2.5 concentrations.

A preliminary comparison of the URBAIR outputs with the observations points out a clear underestimation of the simulated concentrations. The NO_2 observations available for 2015 include measurements from 107 diffusion tubes: 96 of which classified as roadside tubes, 4 as kerbside and 7 as urban background tubes. These diffusion tubes where mainly located in the city centre, over the urban area of Bristol. A set of tubes is also located in the left west part of the domain over the motorway M5. The measurements from the diffusion tubes indicate a minimum concentration of 16.4 $\mu g.m^{-3}$, a maximum concentration of 91.2 $\mu g.m^{-3}$ and an average concentration of 42.1 $\mu g.m^{-3}$.

Besides the diffusion tubes, there was also data available from continuous measurements for 2015, namely 4 continuous measurements points (2 roadside, 1 kerbside, and 1 urban background sites), together with the St Paul's urban background station, which is part of the Automatic Urban and Rural Network (AURN), the UK's automatic monitoring network used for compliance reporting. The annual average NO_2 concentration measured at St Paul's was equal to 22.5 $\mu g.m^{-3}$, while the maximum and the average values from the continuous devices were equal to 44.2 and 36.0 $\mu g.m^{-3}$.

The underestimation of the simulation results is mainly associated with the lack of other emission sources contributing to the concentrations within the area, as well as the background concentrations. Therefore, a procedure was defined to account for the background concentrations and other remaining sources, following the background concentration maps published by the UK's Department for Environment Food & Rural Affairs (Defra). The background air pollution maps made available by Defra are the total annual mean concentrations based on modelled data on 1 km x 1 km grid squares. The background concentrations added to the NO_2 concentrations simulated with URBAIR model included the contributions from the following categories: aircraft, rail, other and rural, while for PM10 and PM2.5 the added background accounted for the following categories: rail, other, secondary PM, residual and salt.

In addition, the simulation results together with the added background concentrations were again calibrated against the measurements through an adjustment procedure. The adjustment procedure comprises the establishment of the linear regression between the measurements, including and the continuous and diffusion tubes measurements, and the simulation concentrations obtained for the cells corresponding to the location of the measurement points. The slope of 1.6154 from the linear regression is applied as a correction factor over all the domain, together with a unique correction factor applied to each cell with a measurements available.

In case of particulate matter, PM10 and PM2.5 concentrations was applied a similar adjustment procedure. However, only the St Paul's station presents valid records for 2015, with an annual average of 14.9 and 10.6 $\mu g.m^{-3}$ of PM10 and PM2.5 concentrations.

Figure 1 shows the NO_2 (Fig. 1a)) and the PM2.5 (Fig. 1b)) annual average concentrations, considering the background concentrations and the adjustment correction factor.

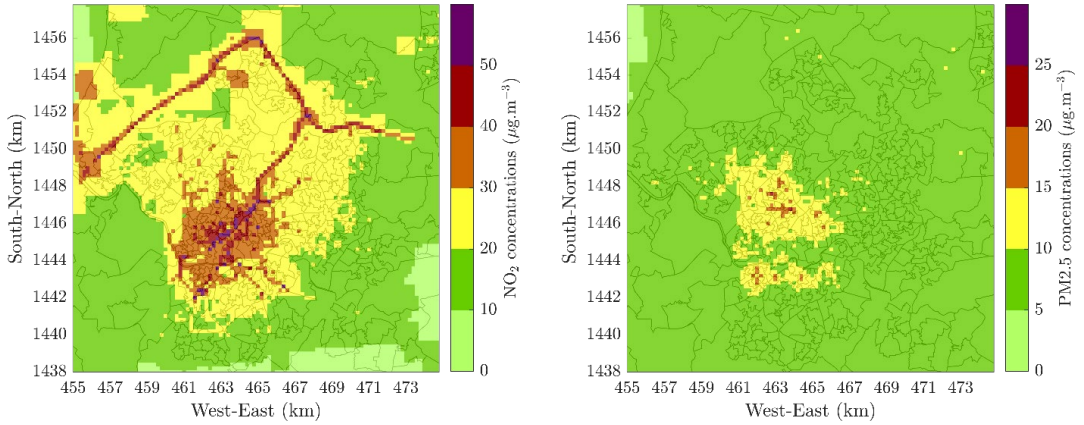

Figure 1. Contour maps of the annual average concentrations of a) NO_2 and b) PM2.5, over the urban area of Bristol, and considering all the emission sectors available on the ClairCity emission database, the background concentrations from Defra, and the adjustment correction factor.

The simulation results indicate a maximum of NO_2 concentration of 91.2 $\mu g.m^{-3}$, simulated within the urban area. The EU annual legal limit value for NO_2 annual concentrations is exceeded within 231 cells. The simulation results denote an important air pollution problem in Bristol linked with the road transport, with hotspots of NO_2 concentrations in the city centre, as well as over the M4 and M5 motorways. On the contrary, particulate matter concentration fields denote no exceedances of the EU legal limit values.

Population exposure

The population exposure was estimated considering the annual average concentrations and the population distribution by each computational grid cell. Table 1 points out the population potentially exposed to NO_2, PM10 and PM2.5 concentrations above the EU legal limit values and the WHO guidelines.

Table 1. Population of Bristol potentially affected by harmful levels of air pollutant concentrations according to the EU limit targets and the WHO guidelines.

Pollutant	EU limit value ($\mu g.m^{-3}$)	Nr of cells exceeding the targets	Population Exposed (%)	WHO guidelines ($\mu g.m^{-3}$)	Nr of cells exceeding the guidelines	Population exposed (%)
NO_2	40	231	5%	40	231	5%
PM10	40	0	0%	20	16	1%
PM2.5	25	0	0%	10	655	25%

Table 1 indicate 231 computational grid cells exceeding the EU targets, which represents 5% of the population potentially affected by harmful levels of NO_2. Table 1 points out no exceedances of the EU legal limit value for PM10 and PM2.5 concentrations. Despite the compliance of the EU legal limit values for particulate matter, the annual concentrations indicate exceedances of the WHO guideline values. Table 1 shows 16 grid cells exceeding the WHO guideline value, which represents nearly 1% of inhabitants potentially affected by PM10 concentrations above the recommended value. PM2.5 concentrations are exceeding the WHO guideline value in 655 grid cells of the computational domain, denoting almost a quarter of population potentially exposed to harmful levels of fine particles.

BAU AND SDW SCENARIOS

The assessment framework was applied to evaluate the impact of Business as Usual Scenarios and scenarios from Stakeholders Dialogue Workshop, considering three time horizons: 2025, 2035 and 2050. The headline air quality and exposure of the BAU and SDW scenarios were quantified as an indicator of the scenarios' potential impact.

Based on the baseline evidence Bristol presents an air pollution problem mainly related with NO_2 concentrations. Therefore, the scenarios analysis will focus on NO2 impact assessment. The significant reductions of the NOx emissions in the BAU scenario will led to relevant reductions of the NO2

concentrations. Figure 2 presents as example the NO2 annual average concentrations considering the impacts of BAU scenarios for 2025 and 2050.

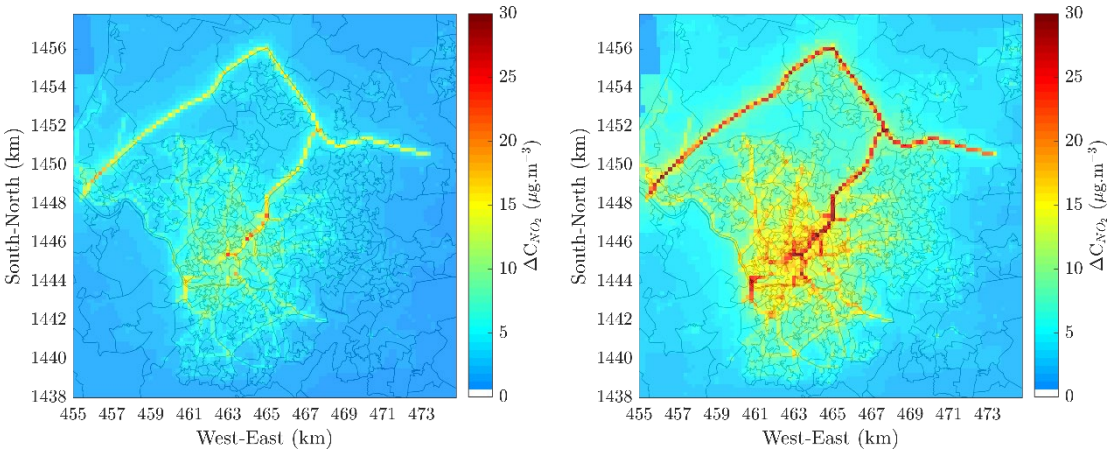

Figure 2. NO_2 annual average concentrations for different scenarios: a) BAU in 2025 and b) scenario 3 from the SDW in 2050.

The maximum concentration will be equal to 43.7 µg.m^{-3} in 2025, corresponding to an overall reduction of the maximum concentration of 37% for the BAU scenario. For all the time-windows of the BAU scenarios the NO_2 exceedances will continue as a problem within the urban area, representing an issue of no compliance with the EU legislation, as well as a potential risk of exposure for the inhabitants of Bristol. The most ambitious scenario will led to strong reductions of NO2 concentrations, being the maximum equal to 26.4, below the EU legal limit value, which corresponds to a reduction of 62% when compared with the baseline.

CONCLUSIONS

This work focuses on the transport and energy related behaviour of Bristol citizens and its contributions to mitigate air pollution and carbon emissions. The ClairCity framework contributes to innovate on the Harmonisation within the Atmospheric Dispersion Modelling for Regulatory Purposes, namely through the source apportionment of current air pollutants emissions and concentrations, as well as, carbon emissions, not only by technology, but by citizens' activities, behaviour and practices, which will be a key outcome of the project.

The outcomes of the assessment of impacts were used to inform the Bristol Policy Workshop run in November 2018 to help decision-makers and local planners to define the final integrated policy unified scenario, including citizens' visions and behaviour. The final integrated scenario will be fully quantified as input to the ClairCity Policy Report to be completed at the end of the process. This Unified Scenario is currently being fully quantified, allowing to take into account local changes, e.g. the Bristol Clean Air Zone.

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