AIR POLLUTION IN THE AVEIRO REGION, PORTUGAL: A CITIZENS' ENGAGEMENT APPROACH

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ABSTRACT

Air pollution has become a growing concern in the past few years, with an increasing number of acute air pollution episodes in many cities worldwide. In Portugal, especially in the region of Aveiro, high concentrations of particulate matter are frequently recorded, being one of the most critical air pollutants. Health impacts related with citizens' exposure to particulate matter has been threatening human health, increasing mortality and morbidity and contributing to a broad range of negative health outcomes. Different causes are attributed to air pollution over Portugal: agricultural, forest fires and dust emissions from Sahara Desert, amongst the natural emission sources, and road-traffic, residential combustion and industrial emissions, amongst the anthropogenic emission sources. Citizens' behaviour has a main role on air quality management. Each day individual choices, such as transportation or residential heating, have direct impact on air pollutant emissions. Therefore, citizens' play an important role to mitigate air pollution problems in their cities. However, the first step is to increase citizens' receptiveness about their contribution to the problem and, at the same time, to engage and empower them to contribute to the solutions. Aveiro Region is one of the case studies of ClairCity (Citizen-led air pollution reduction in cities) project. The project developed several activities to engage citizens on air pollution and carbon emissions issues. This work focus on the Delphi-like approach that includes surveys and workshops, to find out about people's lives in Aveiro Region and their vision for a low carbon, clean air and healthy future region. This paper presents an overview about air pollution in Aveiro region as well as the activities of the Delphi survey to see how citizens perceive this problem and their role on future air quality management.

Keywords: air pollution, citizens' behaviour, ClairCity, Aveiro Region.

1 INTRODUCTION

Urban areas occupy about 1% of the earth's surface. However, they account for half the world's population, consume about 67% of global primary energy and emit around 71% of CO_2 relative to energy consumption [1]. Projections for 2050 indicate that the urban population will reach 70% of the world's population [2] and that energy consumption in cities will increase by 40%. In addition, approximately one third of Europeans living in urban areas are exposed to concentrations of air pollutants exceeding European Union (EU) air quality limit values as defined in Directive 2008/50/EC of May 21st [3]; this figure rises to 90% when compared to the World Health Organization's reference values (which proposes more restricted air quality limit values) [4].

Directive 2008/50/EC on ambient air quality and cleaner air in Europe was launched in 2008 with the aim of improving air quality standards in Europe, preserving ambient air quality when it is good and improving it where standards are exceeded [3]. The transposition of this Directive into the Portuguese legal order was made by Decree-Law no.102/2010 of September 23rd [5].

The complex direct and indirect links between citizens' daily activities and the collective demands they impose on the local and global environment create a challenge that extends beyond the geopolitical frontier of the city, reflecting the need for long-term measures, with the aim of transitioning to a circular economy, with low carbon and cleaner air.

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The reduced civic involvement on air quality issues is partially justified by the absence of "people" in the models and scenarios used to estimate and predict atmospheric pollutant concentrations. The modelling of the emission sources of atmospheric pollutants, without taking into account human activities inducing these emissions, promotes the development of policies, both locally and globally, focused on the mitigation of emissions through technological changes, instead of changing citizens' behaviour. Current practices tend to focus on manifestations of problems rather than their causes, or even their drivers, for example by focusing on air pollution hotspots and activity sectors such as transport, instead of citizen's day-to-day activities and choices that lead to the use of different transports modes. This rationale makes air quality management more dependent on technological innovation than changing citizens' behaviour and does not promote social innovation [6], [7].

It is crucial to develop a new perspective and understanding of air pollution based not only on emission sources, but also on citizen's activities, behaviour and practices, which will allow the link between pollution and human behaviour (daily citizens' practices in urban areas). In conclusion, air pollution and the mitigation of carbon emissions should no longer be seen as separate and purely technological political issues but should be considered as part of citizens' concerns as regards their quality of life and the promotion of a sustainable future.

Existing approaches to air quality management and carbon footprint mitigation are designed to create scenarios for the future, taking into account the current state of the cities (baseline scenario), with the aim of improving air quality and the quality of life. Does this approach lead cities to develop from the perspective of "with what we have now, what is the intended end?" And not "with the end we want to achieve, what do we have to implement today?".

2 THE CLAIRCITY PROJECT

ClairCity aims to improve future air quality and carbon policies in European cities by introducing new modes of engaging citizens, stakeholders and policymakers. Going beyond the current state of the art, ClairCity will put citizens and their behaviours at the centre of air pollution and carbon management. The project will apply the latest advances in social science [8]–[11] 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, leisure) and not to sectors of activity (e.g. domestic, transport, industry) and/or technologies (e.g. diesel vehicles, coal-fired power stations).

2.1 Description of the approach

Involving citizens from six pilot cities with different air pollution challenges (Amsterdam in the Netherlands, Bristol in the United Kingdom, Sosnowiec in Poland, Genoa in Italy, Ljubljana in Slovenia and the Aveiro Region of Aveiro in Portugal), ClairCity are intended to reflect on their impact on air quality and CO_2 emissions based on their daily behaviour and practices (e.g. commuting, shopping).

Future energy and mobility scenarios will be generated depending not only on statistical data, but also on the vision for the future of each citizen, as a result of the activities carried out until the end of the project. Citizens will be able to use data from activities designed to connect their daily actions to the air quality and carbon footprint of their city, with the goal of creating customized solutions for the desired (low carbon) future scenario for their City. In this way, it will be possible to include the aspirations of local people in the modelling of each case study. The results of this dialogue and the engagement process will be evaluated

and will provide information at local, national and European level, resulting in the construction of new policy measures.

The project will be developed in three phases, namely: (i) diagnosis and data collection for each case study; (ii) citizen engagement, analysis of data collected, modelling and construction of future scenarios; and (iii) drawing up a package of policy measures to be applied to each case study, based on the results of the activities carried out with citizens.

2.2 Citizens' engagement

Citizens across the Aveiro region have been engaged in the ClairCity project through a series of activities. These activities, which use a Delphi-like approach, have been conducted over three rounds of engagement.

The first round was a short questionnaire, conducted primarily as face-to-face interviews at events and in public areas, but also as an online survey promoted through networks and social media. The online survey was created using Qualtrics (www.qualtrics.com/uk/). The first round was intended to determine, in broad terms, citizens' main day-to-day activities, their concerns and their views about how these may change over the next 35 years (to 2050). The Round 1 survey in the Aveiro region was conducted from 16th October 2017 to 30th November 2017 and generated 794 responses (464 completed online surveys and 330 from face-to-face interviews).

Round 2 was a purely online survey consisting of mainly closed (multiple-choice) questions. Following the Delphi approach, the purpose of the second round was to enable citizens to reflect on the responses given in Round 1 to shape consensus/dissensus around common theme(s). There were two parts to the questionnaire: the first part sought to explore the activity data obtained from Round 1 in terms of citizens' travel behaviour; the second part aimed to derive citizens' views on a series of policy measures that may be implemented to reduce air pollution and carbon emissions. The online questionnaire was distributed via networks and social media and sent to Round 1 respondents that had expressed an interest in remaining engaged with the project. The Round 2 survey in the Aveiro region was conducted between 15th January 2018 and 20th February 2018 and generated 280 complete responses.

The third round was conducted as two workshops, one in Estarreja (the most industrialized municipality) on 20th February 2018 and one in Ílhavo (the municipality with the highest population density) on 24th February. The workshop in Estarreja had 12 participants and the Ílhavo workshop had 21 participants (Fig. 1).

(a)  (b) 

Figure 1: Round 3 workshops in Estarreja (a) and Ílhavo (b).

The workshops were divided into two sets of activities: Activity 1 – Health and air pollution awareness and Activity 2 – Policy measures. The purpose of the workshop was to explore further how policy measures to reduce air pollution and carbon emissions may be facilitated to reduce negative impacts on citizens' lives and to improve their acceptability. The outcomes from the workshops will inform the development of the policy packages being developed for the Aveiro region as one of the outputs of the ClairCity project.

Round 1 and 2 of the citizen engagement activities in the Aveiro Region showed that citizens have some knowledge about the link between their daily activities and air pollution. The main activities pointed out by citizens as related to air pollution problem are road traffic, residential combustion during the winter, and forest fires in the summer. Although citizens are aware of the main activities of their daily lives that lead to air pollution, this is still not a matter of concern to them, since there is a lack of awareness of air pollution impacts, especially on health.

Round 3 helped bridge this awareness gap and explored what measures citizens would like to implement in the future in their region. Most of the measures discussed are related to the improvement of the public transport network, since most citizens have identified using their car in their daily trips because there are no public transport available to their needs. Other measures, such as the implementation or improvement of green areas, were also discussed.

3 AIR POLLUTION IN AVEIRO REGION

The Aveiro Region is located in the central coastal area of Portugal and includes 11 municipalities, namely Águeda, Albergaria-a-Velha, Anadia, Aveiro, Estarreja, Ílhavo, Murtosa, Oliveira do Bairro, Ovar, Sever do Vouga and Vagos (Fig. 2).

The Aveiro Region has a strong economic and social relevance in Portugal due to its geographical and climate characteristics. The region has the second highest competitiveness index in the country. The expenditure with R&D is the second largest in the country [12]. The predominant economic sectors are manufacturing industry and commerce, which account for 50% and 32% of the region's turnover, respectively [13]. Many chemical and manufacturing companies are located in the region, such as Estarreja Chemical Complex (where several international chemical industries are located, e.g. Air-Liquid, DOW) and the

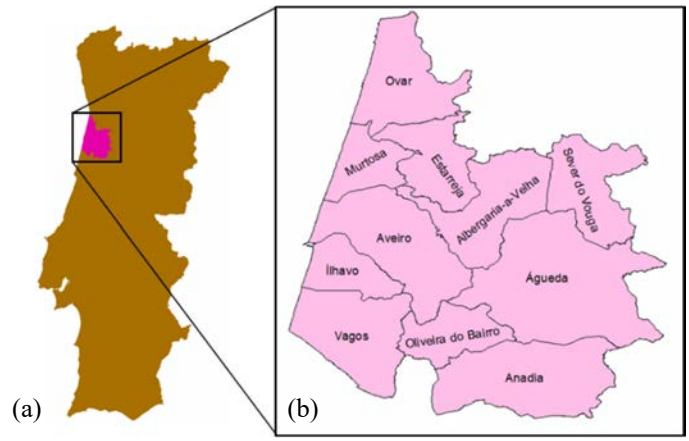


Figure 2: Location of the Aveiro Region in Continental Portugal (a) and distribution of the municipalities that comprise it (b).

Navigator Company, a pulp and paper producer, located in Aveiro municipality, with a turnover that represents almost 1% of the national GDP.

Aveiro also harbours an important commercial port not only for general cargo but also for oil and gas as there is a large oil refinery in the region. Being such a busy port (fishing and commercial) the ancillary sector is also strong, ranging from shipyards for maintenance and shipbuilding, cold storage, manufacture and maintenance of fishing gear, etc. All these ancillary activities contribute significantly to the local economy. The Port register a movement of about 5 million tons of goods per year [14]. The seaport also has a railway infrastructure connected to the rail corridor of the Trans-European Transport Network. The highway access is lightly jammed and it connects the seaport to the country's main cities, as well as to Spain [15].

3.1 Emissions of air pollutants

Particulate matter, with a diameter equal to or less than 10 μm (PM10), is the most problematic air pollutant in the Aveiro Region with frequent exceedances to the legislated limit values. PM10 is the air pollutant with the highest risk to human health, related to the development of heart and respiratory diseases, such as asthma, bronchitis and pulmonary emphysema [16].

In the Aveiro Region, the most important source areas of PM10 are Estarreja and Aveiro municipalities, with 41% and 28%, respectively, of the total emissions (Fig. 3(a)). In Estarreja, where an important Industrial Petrochemical Complex is located, industrial combustion and processes are responsible for the largest PM10 emissions. In the most of the remaining municipalities, industrial combustion and processes still being the main contributor to PM10 emissions, followed by residential and commercial combustion and road traffic (Fig. 3(b)) [17].

Increasing citizens' awareness of the problems associated with PM10 emissions, both at the environmental and human health levels, could lead, for example, to a reduction in the use of biomass in residential heating equipment.

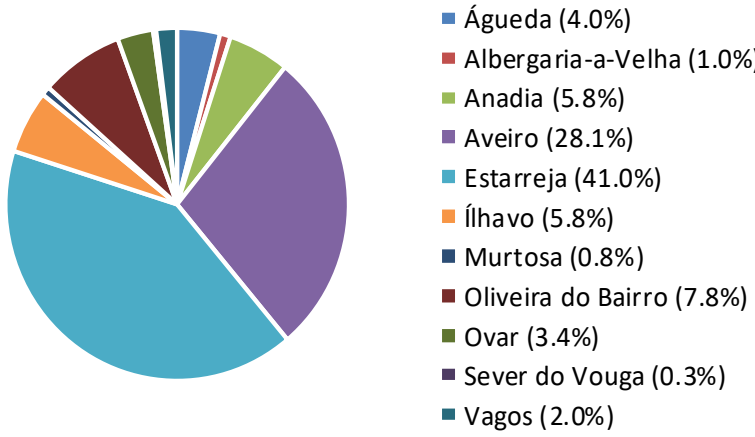
3.2 Air quality

In Portugal, in particular over the coastal areas, where the Region of Aveiro is included, high concentrations of PM10 are recorded [18]. In order to protect human health, the daily limit value (LV) of 50 $\mu g.m^{-3}$ of PM10 was established, which should not be exceeded by more than 35 days per calendar year. In recent years, according to the State of the Environment Reports developed by the Portuguese Environment Agency, the air quality monitoring stations located in the Aveiro Region (described below) have recorded the highest concentrations of PM10 in the country [19]–[22]. From these results, it is possible to understand the air quality problem registered in the Aveiro Region.

In the Aveiro Region there are three air quality monitoring stations managed by the Regional Coordination and Development Commission of the Center (CCDRCentro), namely: (i) Aveiro, (urban environment with road traffic influence); (ii) Ílhavo, (suburban environment with background influence); and (iii) Estarreja, (suburban environment with industrial influence). All these stations are measuring PM10 concentrations.

The daily average PM10 concentrations measured at the three air quality monitoring were analysed for the entire year of 2017 (Fig. 4), showing several air pollution episodes with multiple exceedances to the legislated limit value (50 $\mu g.m^{-3}$), in all air quality monitoring

(a)



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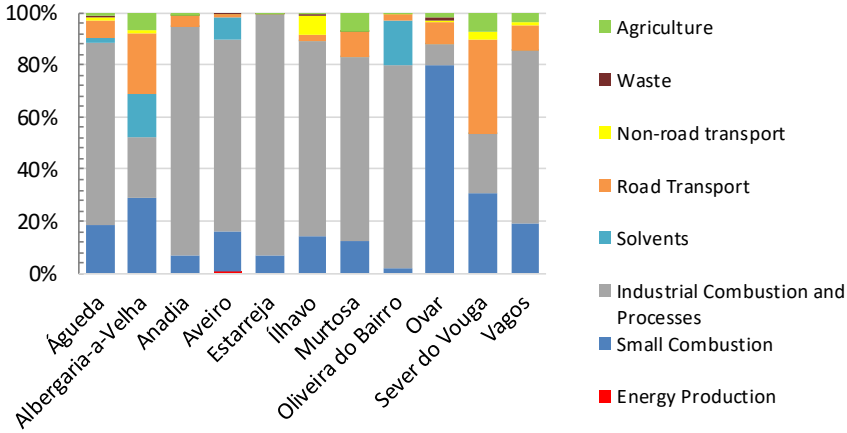

Figure 3: Contribution of the different municipalities (a) and sectors (b) in the emission of PM10 for the Aveiro Region in 2015.

Table 1: Number of exceedances of the limit value and the annual average concentration of PM10, for each air quality monitoring station in Aveiro Region in 2017.

	Number of exceedances to limit value	*Annual average concentration (in $\mu g.m^{-3}$)*
Estarreja	22	23.8
Aveiro	19	23.7
Ílhavo	14	20.6

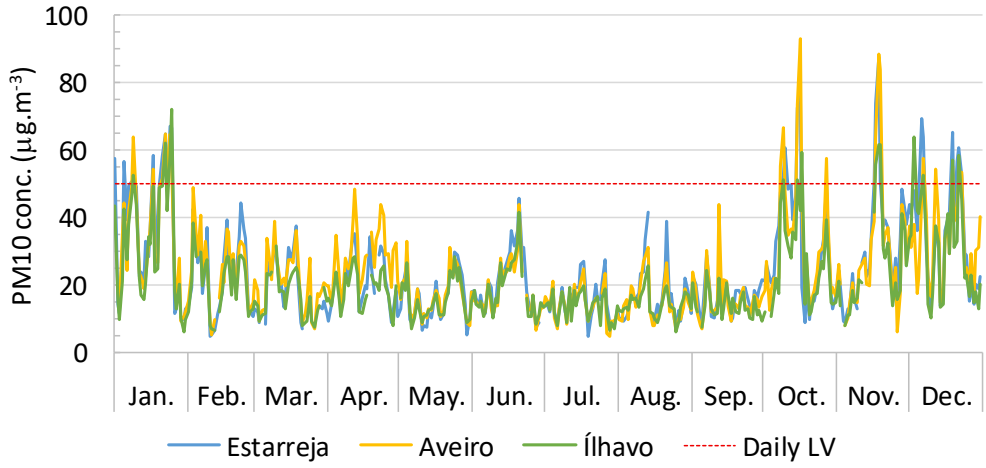

Figure 4: Daily average of particulate matter concentrations measured in the air quality stations located in Aveiro Region in 2017.

station. Table 1 shows the number of exceedances to the limit vale and the annual average concentration of PM10, for each air quality monitoring station.

PM10 concentrations are higher in January, October, November and December, being their main causes i) the biomass burning for residential heating in the cold months (January, November and December); and ii) severe wild forest fires recorded in October.

To better understand the episodes of PM10 air pollution recorded in the cold months, hourly concentrations of PM10 were analysed during a cold wave. The period selected for analysis was January 20th to 26th. This was the period during 2017 with the lowest temperatures (Fig. 5). For all days, the PM10 concentrations show minimum values between 14–16h, and the highest around midnight.

Two main factors can justify this occurrence: (i) the evening emissions of PM10 from domestic sources such as residential combustion of biomass [18], [23]–[25]; this fact is visible, and a clear odour of burning wood can be detected; and (ii) the decrease in temperature at the end of the day contributes to atmospheric stagnation conditions. These conditions prevent dispersion, increasing air pollutants concentrations and resulting in their accumulation in the lower atmosphere. These factors are most important during the cooler months due to the lower temperatures recorded overnight [25].

Although the lowest temperatures were registered before sunrise, it seems that, for this period, the PM10 concentrations decrease gradually, which supports the assumption of residential combustion of biomass as a major factor in these episodes of local air pollution.

At the end of the day of 25th January, the temperature remained relatively high during the night, associated to a precipitation episode. This change of the meteorological conditions promoted the removal of the atmospheric pollutants and, consequently, the reduction of PM10 concentrations and improvement of air quality. This occurrence was registered on the 26th January in all the air quality stations analysed.

All other episodes of PM10 air pollution recorded in the cold months occurred under conditions similar to those previously mentioned, with cold waves or influences of polar air masses in the Aveiro Region [26]–[28].

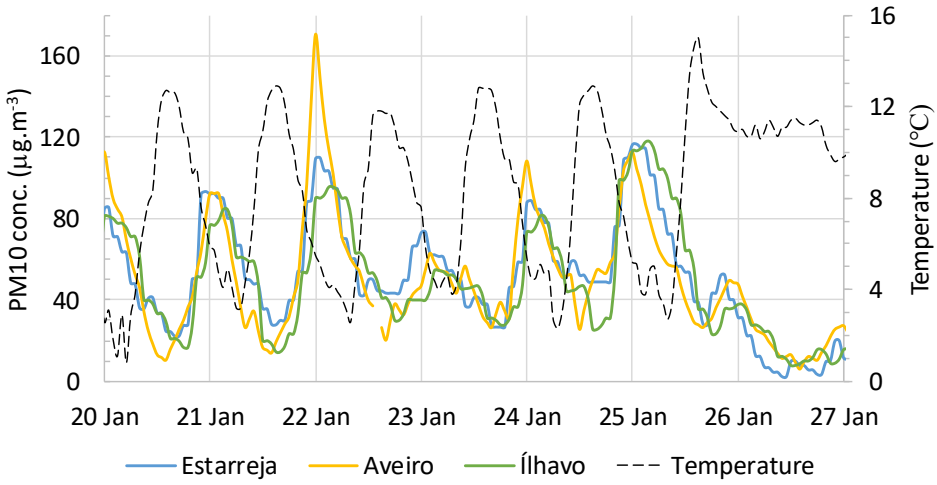

Figure 5: Hourly PM10 concentrations measured in the air quality stations located in Aveiro Region and hourly temperature measured at the meteorological station of the University of Aveiro.

4 CONCLUSIONS

Currently, air pollutants concentrations recorded in European urban areas exceed the values recommended by the European Environment Agency and the World Health Organization. For this reason, it is essential to work on solutions to reduce emissions of air pollutants and consequent reduction of current concentrations. The ClairCity project aims to raise citizens' awareness of European cities and regions to the effects of air quality deterioration and carbon emissions on human health. Through the direct participation of citizens in specific activities, it will be possible to understand their vision for the future of their city / region.

The complex direct and indirect links between citizens' daily activities and the collective demands they impose on the local and global environment mean that policies currently being developed should no longer focus on mitigation of emissions through technological change and focus on individual and social behaviour of each citizen. Therefore, it will be possible to move to a low-carbon circular economy and to improve air quality in urban areas. The ClairCity project will be able to produce a package of measures and policies that reflect the vision and needs of citizens for the future of their city / region (based on activities involving direct citizen participation), ensuring a sustainable future, good air quality, low carbon emissions, reduced exposure to air pollutants and improved quality of life for citizens.

The engagement activities in the Aveiro Region showed that, although citizens are aware of the main activities of their daily lives that lead to air pollution, this is not yet a concern for them, since there is a lack of awareness of the impacts of air pollution, especially on health.

For the case study of the Aveiro Region, PM_{10} concentrations recorded by the air quality monitoring stations in the region were analysed. This analysis allowed to conclude that the residential combustion of biomass is an important source of emission of atmospheric pollutants in the Region. It is crucial to alert the population to the negative effects on health of the use of this equipment for heating, and the ClairCity project has a fundamental role in this matter.

In order to solve the problem of the degradation of air quality, it is necessary to act not only at the technology level, but also at the social level, since the citizens do the use of the available technology. From this point of view, it is necessary to look at the citizen not only as being the cause of atmospheric pollution, but mainly as being an essential part of the solution.

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