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A New Air Quality Index for Cities

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1. Introduction

Global population growth has led to increased populations living in urban areas. Often, this enhances stresses on space, ecosystems, infrastructures, facilities and personal lifestyles. Problems related to quality of life in cities are increasingly relevant, especially with regard to environmental issues.

Due to a generalised increase of mobility and road traffic in urban areas, the total emissions from road traffic have risen significantly, assuming the main responsibility for the disregard of air quality standards. In urban environment the typical anthropogenic sources are mainly the road traffic and, when existing, the industrial activity.

The quantitative evaluation of traffic air pollution levels is the basis on which air pollution control policies stand. The evaluation of air quality may be occasional or long-term. Occasional evaluation is useful in the context of information and alert systems for the population, working normally in real or almost-real time. Data is acquired through measurements made on an hourly or daily average basis and concentration episodes are evaluated and reported. When long-term data is considered, then we talk about long-term trend analysis, this kind of approach can be adequate for identifying the major emission source contributors to urban pollution (Butterwick et al. 1991).

In order to find an air quality index, the pollutant concentrations are combined through a classification scale anchored on the legal limits and, on the other side, on the impacts over human health. Typically these classification models consider only the worse pollutant, i.e. the one which concentration is higher given a certain scale. Two air quality evaluation models are referred, both working in real time: a Canadian and a Portuguese experience.

The objective of this chapter is to present a new air quality index, cityAIR, developed for urban contexts. The mathematical formulation of cityAIR stands on two logics: whenever at least one of the pollutants considered overcomes the legal limits for the concentration, this will be the only relevant one for the index calculation, and the value will be the minimum of the scale (zero or red); when there is no limit violation, then all the pollutants are considered for the overall air quality, which is calculated through a multi-criteria combination of the concentrations, where trade-off is allowed.

A case study is presented for Viana do Castelo, a mid-sized Portuguese city, in which cityAIR values were calculated in consideration of concentrations of CO, NO_2, O_3, C_6H_6 and PM10.

2. Urban air pollution

Urban air pollution became one of the main factors of degradation of the quality of life in cities. This problem tends to worsen due to the unbalanced development of urban spaces and the significant increase of mobility and road traffic. As a consequence, the total emissions from road traffic have risen significantly, assuming the main responsibility for the disregard of air quality standard (Butterwick, L. et al., 1991).

The atmospheric pollutants are emitted from existent sources and, subsequently, transported and dispersed several times in the atmosphere before reaching receptors through wet deposition (rainout and washout by rain and snow) or dry deposition (particle adsorption). In an urban environment, typical anthropogenic sources are mainly the road traffic and, when existing, the industrial activity. Emissions from mobile sources contribute to primary and secondary air pollution that can threaten human health, damage ecosystems and influence climate (Sharma et al. 2010; Nagurney et al. 2010). Traffic patterns, vehicle characteristics, and street configurations have a cumulative effect on exhaust emissions (Pandian et al. 2009).

The combustion of hydrocarbon fuel in the air generates mainly carbon dioxide (CO_2) and water (H_2O). However, the combustion engines are not totally efficient, which means that the fuel is not totally burned. In this process the product of the combustion is more complex and could be constituted by hydrocarbons and other organic compounds as well as benzene (C_6H_6), carbon monoxide (CO) and particles (PM) that contain carbon and other pollutants. On the other hand, the combustion conditions - high pressures and temperatures - originate partial oxidation of the nitrogen present in the air and in the fuel, forming oxides of nitrogen (mainly nitric oxide and some nitrogen dioxides) conventionally designated by NO_x.

Traffic-related air pollution levels can be evaluated by either direct measurements or predictive models. The direct measurement method is only feasible for evaluating actual situations; predictive methods can be applied throughout the planning process from the initial concept to the final detailed design of air pollution abatement measures. However measurements provide essential information to validate the predictive methods.

Numerous available dispersion models represent an important set of tools for simulating air pollution scenarios. The model adopted for this research was developed by Cambridge Environmental Research Consultants (CERC) in the United Kingdom.

This model has been used by local authorities all over Europe for urban air quality forecasting (Carruthers et al., 1997, 1998, 2003; Timmis et al, 2000; McHugh et al., 1997).It uses a parameterisation of boundary layer physics in terms of boundary layer depth and Monin-Obukhov length, and it applies a skewed-Gaussian concentration profile for convective meteorological conditions. For stable and neutral meteorological conditions, the model assumes a Gaussian plume for the concentration profile distribution with reflection at the ground and in the inversion layer.

The dispersion model has a meteorological processor for input variables, which typically include day of the year, time of day, cloud cover, wind direction and speed and temperature. These variables are used to calculate model parameters such as boundary layer depth and Monin-Obukhov length. The model does not account for anthropogenic heat sources.

An additional and important feature that makes this dispersion model suitable for modelling the urban environment is a chemistry scheme that facilitates the calculation of chemical reactions between nitric oxide, nitrogen dioxide, ozone and volatile organic compounds in the atmosphere.

2.1 Existing air quality evaluation models

The evaluation of air quality may be occasional or long-term. Occasional evaluation is useful in the context of information and alert systems for the population, working normally in real or almost-real time. Data is acquired through measurements made on an hourly or daily average basis and concentration episodes are evaluated and reported. When long-term data (6-month or yearly evaluations) is considered, than we talk about long-term trend analysis.
In the following subchapters two air quality evaluation models are referred, both working in real time: a Canadian and a Portuguese experience.

2.1.1 AQI, Canada

Integrated in a public information system of Vancouver, the FPCAP (Federal-Provincial Committee on Air Pollution) provides the information on pollution levels in form of an Air Quality Index (AQI). The AQI is based on measurements taken throughout the region of Greater Vancouver (Butterwick et al., 1991).
The AQI is expressed as a single value taking into consideration the concentrations of five major air pollutants (CO, NO_2, O_3, SO_2, PM). The index is based on the pollutant with the highest concentration relative to Federal and Provincial air criteria. This pollutant is called the Index Pollutant. The values of the other four pollutants are then disregarded.
The numeric value of the Air Quality Index is correlated to a classification system. For each category of air quality, information is provided on the associated general health effects and recommended precautionary action. Table 1 summarizes this information.

AQI	Air Quality	General Health Effects	Cautionary Statements
0 – 25	Good	No measured effects are associated	No precautions are necessary
26 – 50	Fair	Is adequate protection against effects on general population	No precautions are necessary
51 – 100	Poor	Short-term exposure may result in irritation or mild aggravation of symptoms in sensitive persons.	Persons with heart or respiratory ailments should reduce physical action and outdoor activity
Over 100	Very poor	Significant aggravation of persons with heart and lung disease. Many people may notice symptoms.	Persons with respiratory and cardiovascular diseases should stay indoors and minimize physical activity.

Table 1. Great Vancouver Air Quality Index. Source: (Butterwick et al., 1991)

2.1.2 QualAr, Portugal

The APA (Agência Portuguesa do Ambiente) of the Ministry of Environment of Portugal provides public information on pollution levels based on measurements taken through a pollution monitoring network. The information on pollutant levels is presented as an index called "Índice de Qualidade do Ar" (QualAr) (APA, 2011). The QualAr is based on 24–hour average concentrations, and therefore does not reflect short term peak levels.

The QualAr is expressed as a single value taking into consideration the concentrations of five major air pollutants (CO, NO_2, O_3, SO_2, PM). The index is based on the pollutant with the highest concentration relative to the Portuguese annual limit values for the protection of human health. The values of the other four pollutants are then disregarded. The calculation of QualAr takes into account the following averages:

- Nitrogen Dioxide (NO_2) – hourly average
- Sulphur Dioxide (SO_2) – hourly average
- Ozone (O_3) – hourly average
- Carbon Monoxide (CO) – 8-hour average
- Suspended Particulates (PM10) – daily average

The air quality assumes the classification from Poor to Good according to a classification system summarized in the Table 2.

Pollutant	CO (µg/m^3)		NO_2(µg/m^3)		O_3(µg/m^3)		PM10(µg/m^3)		SO_2(µg/m^3)	
Classification	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Very Poor	10000	-----	400	-----	240	-----	120	-----	500	-----
Poor	8500	9999	200	399	180	239	50	119	350	499
Fair	7000	8499	140	199	120	179	35	49	210	349
Good	5000	6999	100	139	60	119	20	34	140	209
Very Good	0	4999	0	99	0	59	0	19	0	139

Table 2. Classification of QualAr for 2010.Source: (APA, 2010)

The classification of the air quality is based on the pollutant with the highest concentration relative to the Portuguese annual limit values for the protection of human health (Decreto-Lei 102/2010), [i.e. for an atmosphere with pollutants levels SO_2 - 35 µg/m^3 (very good), NO_2 - 180 µg/m^3 (fair); CO - 6000 µg/m^3 (good), PM10 - 15 µg/m^3 (very good) and O_3 - 365 µg/m3 (very poor): Air Quality was Very Poor due to Ozone].

3. The cityAIR index

Both models presented above are approaches which prevent trade-off between pollutant concentrations because they are based on the pollutant with the highest concentration relative to the legal limits. For situations where the concentrations are below the legal limit, i.e. when there is no limit violation, a model integrating all the pollutants could offer a more complete evaluation of the air quality. Such a model requires that whenever at least one of the pollutants considered overcomes the legal limits for the concentration (or any other limit assumed for this purpose), this one will be the only relevant for the index calculation, and the value will be the minimum of the scale.

A multicriteria air quality index is proposed, which allows for trade-off between pollutants whenever concentration values stay under the considered limits.

The cityAIR model proposed stands on the combination of long-term concentrations, which may result from past measurements or, differently, from mathematical simulation models providing in this case a prospective view of air quality.

When air pollution concentrations are computer-simulated for a city, the values for each point or area considered are compared to a standard (in this paper the legal limit). This comparison generates a dummy variable: zero if the standard is exceeded and one if it is not.

The cityAIR index results from the weighted linear combination of normalised concentration values, which are subjected to the product of the dummy variables (eqn 1).

$$cityAIR = \sum_i w_i \, c_i \prod_i v_i \tag{1}$$

Where:
w_i is the relative weight of the pollutant i;
c_i is the normalised concentration of the pollutant i;
v_i is the dummy variable of the legal limit violation L_i of pollutant i, defined as follows:
$v_i = 1$ when $c_i \leq L_i$
$v_i = 0$ when $c_i > L_i$
The proposed model makes use of multi-criteria techniques for combining, aggregating and standardising pollutant concentration data.

3.1 Pollutants and weights

The selection of pollutants to be included in the cityAIR index may vary according to the type of sources or even the data availability. For the purpose of this paper we present the pollutants considered in the case study, which are typically result from road traffic:
CO: Carbon Monoxide
NO_2: Nitrogen Dioxide
PM10: Particulate< 10 μm
C_6H_6: Benzene
O_3: Ozone
Equal weights were considered, which means 0.2 for each of the five pollutants.

3.2 Normalization of concentrations

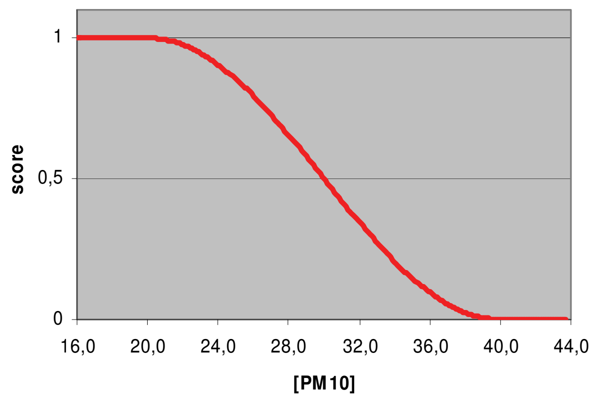
Because of the different scales upon which concentrations are measured, it is necessary to standardize them before aggregation. The process of standardisation is essentially identical to that of fuzzification in fuzzy sets. Standardisation is intended to transform any scale into a normalised range (i.e. zero to one). In our case, the results express a membership grade that ranges from 0.0 to 1.0, representing a continuous spectrum from non-membership (bad air quality) to complete membership (very good air quality), on the basis of the criterion (pollutant concentration) being fuzzified.
For the standardization a sigmoidal function has been adopted (eqn 2).

$$score = \frac{1}{\sin^2 \alpha} \cos^2 \alpha \tag{2}$$

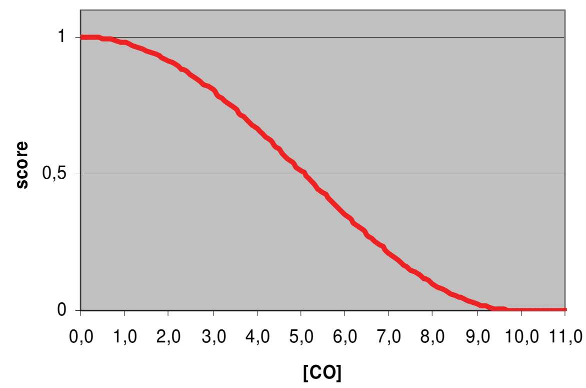
Where,

$$\alpha = \left[{(x - x_a)}/{(x_a - x_b)} \right] \times {\pi}/{2} \tag{3}$$

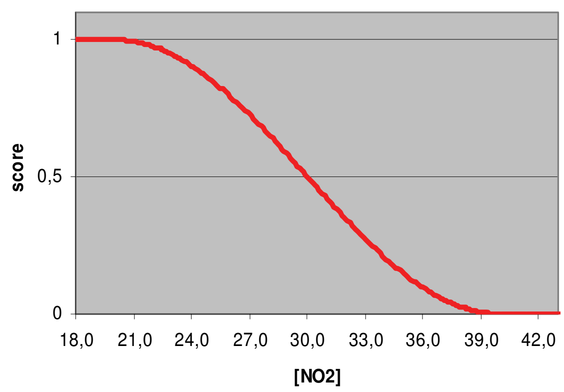
Where x is the concentration value being normalized, and x_a and x_b are control points in the function. Figures 1a to 1e present this function graphically for each of the five pollutants. The control points adopted (a and b) are listed in Table 3.



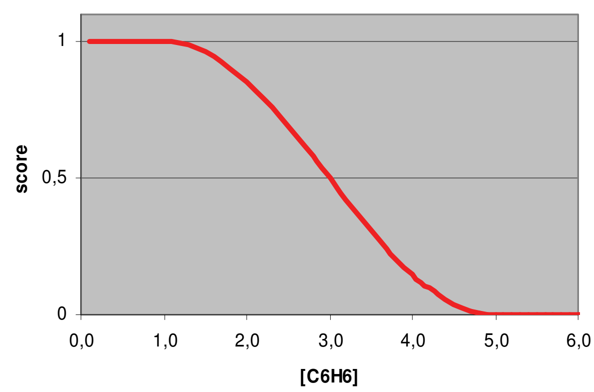
a) Fuzzy function of PM10



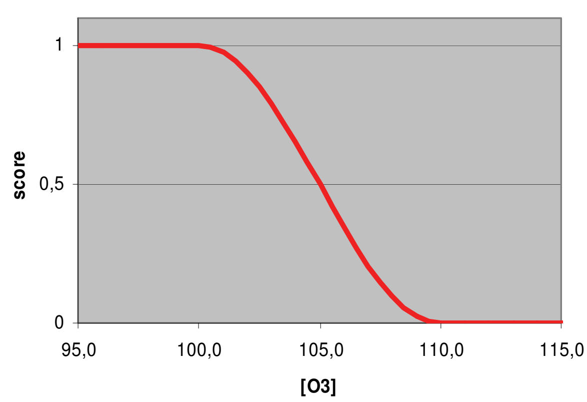
b) Fuzzy function of CO



c) Fuzzy function of NO_2



d) Fuzzy function of C_6H_6



e) Fuzzy function of O_3

Fig. 1. Normalisation functions

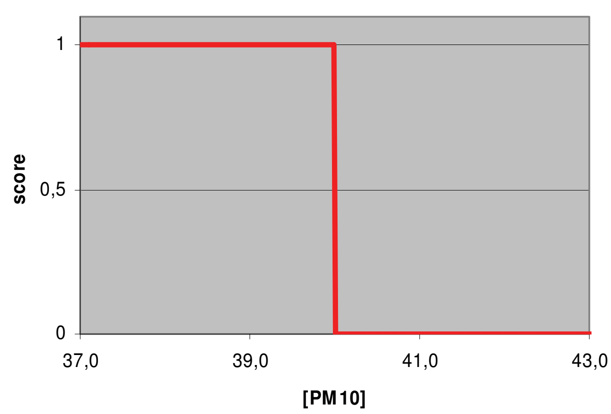
Control points of the sigmoidal functions were selected according to the following criteria: score = 0 for the concentration limit values considered in the Portuguese legislation for human health protection and score = 1 for the concentration guidance values recommended by the World Health Organisation (WHO, 2005)(NO2 and CO values represented a non-polluted atmosphere (Seinfeld, 1997). Table 3 presents the adopted values.

Pollutants	Score = 0	Score = 1	Averaging period
CO	[CO] > 10.0 mg/m^3	[CO] ≤ 0.140 mg/m^3	8 hours (rolling average) for calendar year
PM	[PM10] > 40.0 µg/m^3	[PM10] ≤ 20.0 µg/m3	Calendar year
NO_2	[NO_2] > 40.0 µg/m^3	[NO_2] ≤ 20.0 µg/m^3	Calendar year
O_3	[O_3] > 110.0 µg/m^3	[O_3] ≤ 100.0 µg/m^3	8-hour average for calendar year
C_6H_6	[C_6H6] > 5.0 µg/m^3	[C_6H_6] ≤ 1.0 µg/m^3	Calendaryear

Table 3. Control points of the fuzzy functions

3.3 Dummy variables

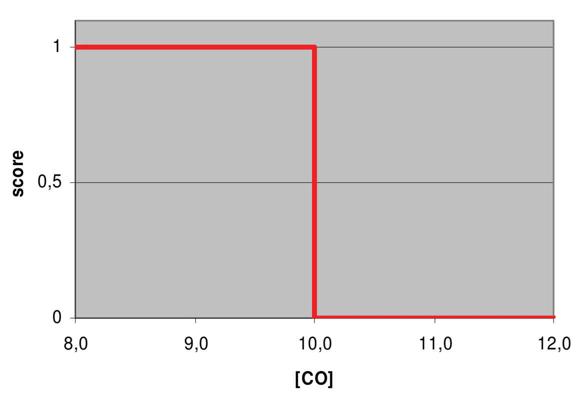
Dummy variables switch from zero to one at the concentration limits mentioned above (third column of Table 3). Figures 2a to 2e show a graphical view of the dummy variable functions.



Where
score = 1 when [PM10]≤ 40 µg/m^3
score = 0 when [PM10] > 40 µg/m^3

[PM10] = calendar-year average concentration, expressed in µg/m^3.

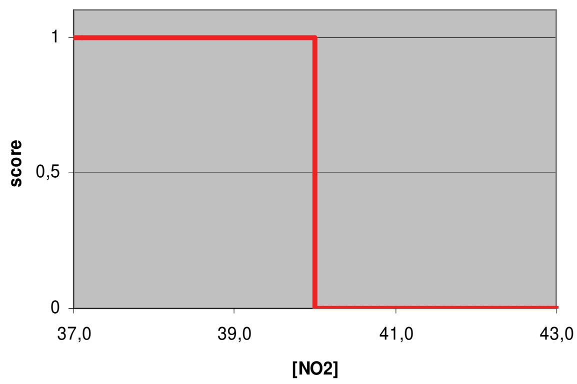
a) Dummy variable function of PM10



Where
score = 1 when [CO]≤ 10.0 mg/m^3
score = 0 when [CO] > 10.0 mg/m^3

[CO] = 8-hour rolling average concentration for the calendar year, expressed in mg/m^3.

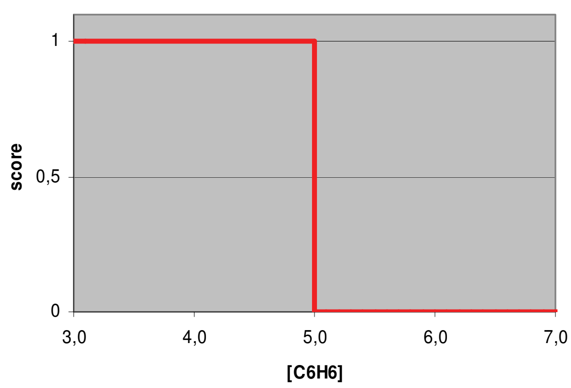
b) Dummy variable function of CO



Where
score = 1 when $[NO_2] \leq 40\ \mu g/m^3$
score = 0 when $[NO_2] > 40\ \mu g/m^3$

[NO2] = calendar-year average concentration, expressed in $\mu g/m^3$.

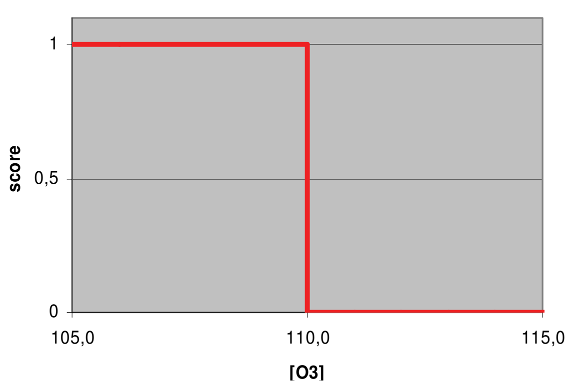
c) Dummy variable function of NO_2



Where
score = 1 when $[C_6H_6] \leq 5.0\ \mu g/m^3$
score = 0 when $[C_6H_6] > 5.0\ \mu g/m^3$

$[C_6H_6]$ = calendar-year average concentration, expressed in $\mu g/m^3$.

d) Dummy variable function of C_6H_6



Where
score = 1 when $[O_3] \leq 110\ \mu g/m^3$
score = 0 when $[O_3] > 110\ \mu g/m^3$

[O3] = 8-hour rolling average concentration for the calendar year, expressed in mg/m^3.

e) Dummy variable function of O3

Fig. 2. Dummy variables

4. Case Study: Air quality index of one mid-sized city

A case study was undertaken to evaluate urban environmental quality in the Portuguese city of Viana do Castelo, which is located on the north-western seaside.
This mid-sized city has a population of around 36,000 in an overall area of 37 km2. The most notable source of noise and air pollution is a main road (Avenida 25 de Abril) that crosses the city and divides it into two parts.
Based on traffic data and the physical characteristics of the area, horizontal concentration maps were created for five main pollutants: CO, NO_2, C_6H_6, PM10 and O_3. A range of numerical models were used to produce results.
The ADMS-Urban model was used for pollutant dispersion. The Hills model was used to calculate air flow and turbulence over complex terrain and to account for the effects of variable surface roughness (CERC, 2001). The COPERT4 model (COPERT4), which is based on CORINAIR v.5 (CORINAIR, 2006), was used to estimate traffic emissions.

4.1 Air pollution of Viana do Castelo

The sources characterization data, and considering that Viana do Castelo is a touristic seaside city, two traffic counting campaigns were carried out, one in winter time and another one in summer time, of which resulted the data for two scenarios. Each campaign included most of the city streets and traffic was counted round-the-clock in a typical week day.
Main and secondary roads were modelled explicitly, as were one pulp and paper mill located in the vicinity of the city. The factory was modelled as one point source that represents the stack.
One single profile was developed to represent the hourly variation of traffics flows on all the roads. A full survey, including topographic characteristics, surface roughness and the specification of the emission sources, cross and longitudinal profiles (for canyon roads) was carried out for the whole city.

4.2 Validation

There is no direct technique for determining if a model is good or bad because model performance depends on so many factors. These are related with model input data, model set-up parameters and model algorithms. Besides model performance depends on the averaging time for the pollutant concentration, the pollutant itself and the monitoring sites locations. Much research has gone into prepare acceptable validations techniques. The usually used BOOT statistics approach derives from that of Hanna and Paine (Hanna & Paine, 1989) and employs a series of statistical measures comprising the mean, correlation, normal mean square error and fractional bias. The methodology adopted was based in BOOT statistical approach.
For the validation process it was guaranteed the same meteorological conditions, the same geographical base and the same reading points (coordinates x, y, z). Pollutant concentrations are predicted for each hour of the monitoring period. For hours with inadequate met data predictions are not made and the corresponding measured values are neglected.
The following simplifications were assumed:
The same flow and composition of traffic and the same traffic daily profile in both periods (measurement and modelling period);

- The validation process was developed at two levels:

- averaging the data in order to obtain daily concentrations profiles, both for monitored and predicted data;
- for each monitoring site comparison of the averaged daily concentrations profiles by the BOOT statistical methodology.

- The pollutant used in the validating process was CO, a primary and typical road traffic pollutant.

Pollutants were measured at three monitoring sites in the city (Fig. 3) during the monitoring periods shown in Table 4.

Monitoring sites	Monitoring periods
A1	0h00 19.Jan. to 24h00 21.Jan
A2	0h00 23.Jan. to 24h00 25.Jan
A3	0h00 30.Jan. to 24h00 1.Feb

Table 4. Monitoring periods

Point A1 is located at the Largo João Tomás da Costa, next to the River Garden. This site is particularly influenced by the road traffic that circulates near the garden.
Point A2 is located in the Campo do Castelo, a large square where some outdoor activities take place.
The third point, A3, is located in Rio Lima's Street, at the South edge of the City's Park and close to highway A28.

Fig. 3. Automatic monitoring sites in Viana do Castelo

The statistics calculated include Average, Standard Deviation, Normalised Mean Square Error (NMSE), Fractional Bias (FB) and the FAC2. The data format was hour by hour for the measured concentrations and predicted concentration. A perfect model would have FAC2=1.0, NMSE=0.0 and FB=0.0.
The Table 5 present statistics of comparisons between measured concentrations and the ADMS-Urban calculations. Statistics have been calculated based on hourly comparisons for each site (A1, A2 and A3) and for overall statistics (Ov.S.).
Figures 4 to 6 compare the predicted (ADMS-Urban calculations) and observed (measured) average daily concentrations of CO at the monitoring sites A1, A2 and A3.

Monitoring Sites	Average		Standard deviation		FAC2 (objective 1)	NMSE (objective 0)	FB (Objective 0)
	Monit.	Pred.	Monit	Pred.			
A1	0.34	0.42	0.0888	0.0233	1.28	0.172	-0.20
A2	0.71	0.67	0.3184	0.0956	1.14	0.172	0.06
A3	0.31	0.33	0.0942	0.0550	1.10	0.049	-0.05
Ov.S.	0.46	0.47	0.1671	0.1322	1.17	0.131	-0.06

Table 5. Monitored and predicted CO concentrations (µg/m3)

The comparison of the output of ADMS-Urban with pollutant concentrations measured in the control points has confirmed the generally good performance of the model.
The variations of the mean concentrations along the day, shown in Figures 4 to 6, reveal a quite fair agreement between predicted and measured values.

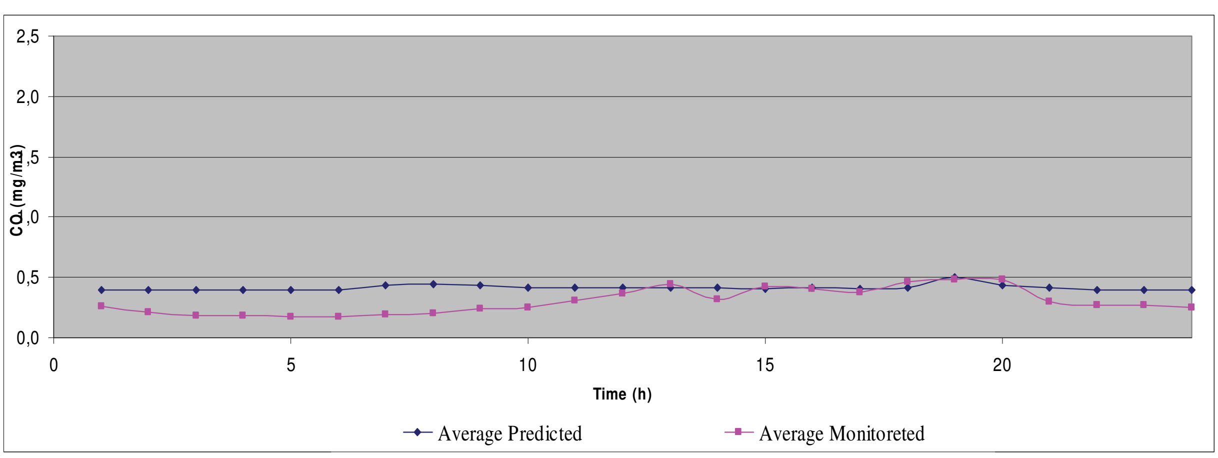


Fig. 4. Temporal variation at A1

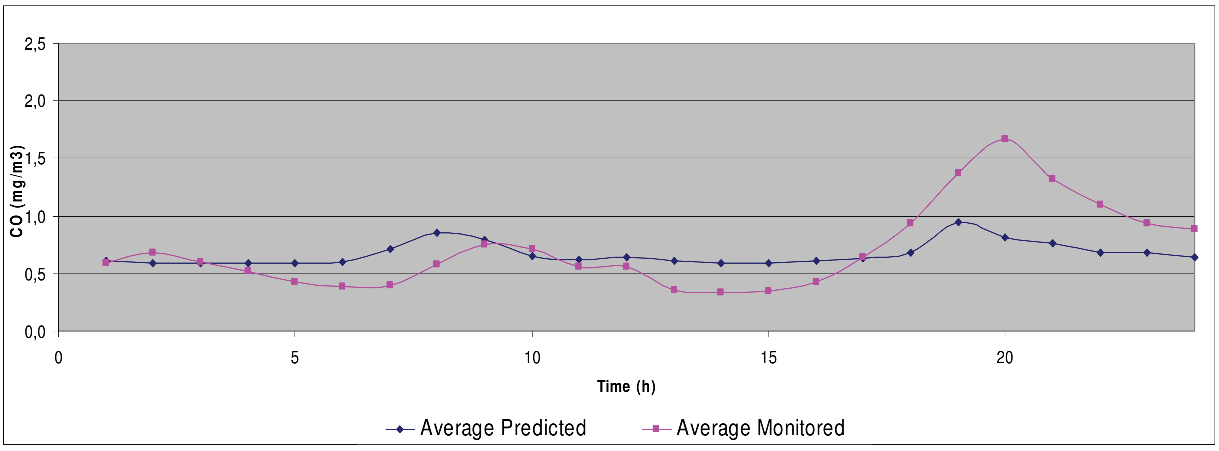


Fig. 5. Temporal variation at A2

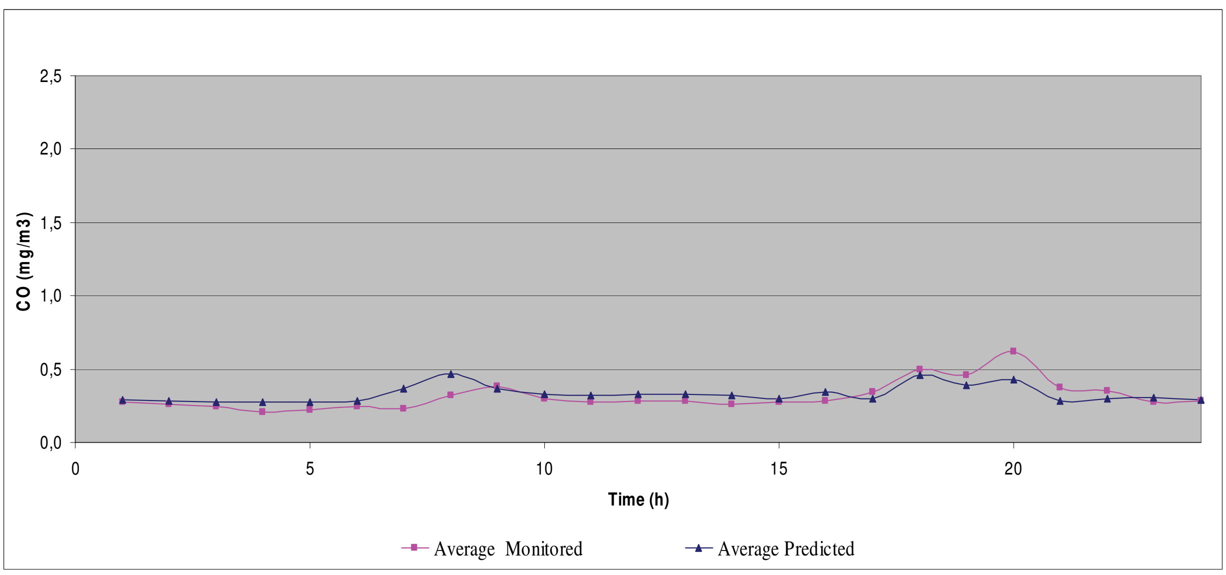


Fig. 6. Temporal variation at A3

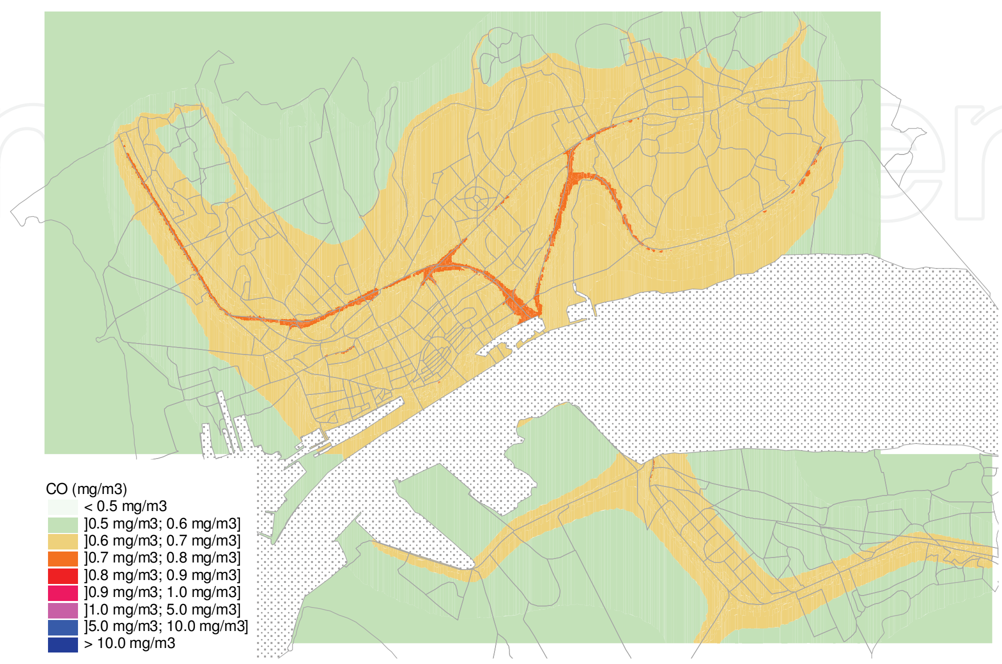
4.3 Air pollutant maps

Horizontal concentration maps were created using ADMS-Urban model. These maps represent the average atmospheric pollution situation in one year. The following calculation parameters were adopted:

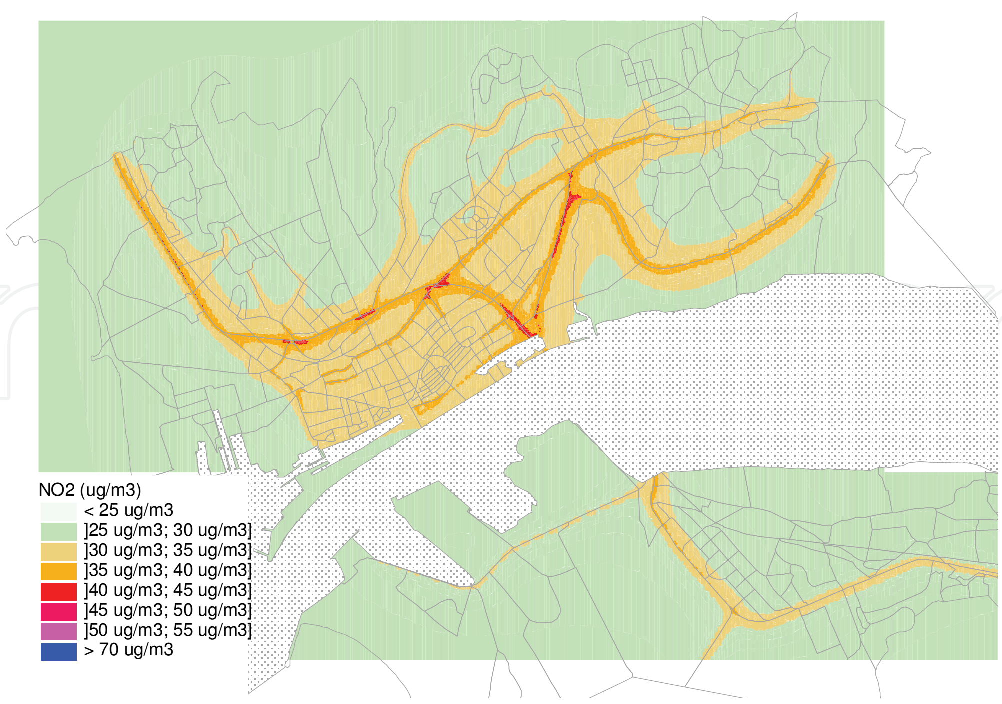
- Grid spacing: variable grid spacing (less than 10 meters);
- Height of the map: 1.20 m;
- Meteorological conditions: Data gathered at the automatic monitoring sites for one year (hourly);
- Monin-Obukhov length: 30 m ;
- Surface roughness: 0.5 m;
- Emissions inventory: database prepared for Viana do Castelo including road sources and industrial sources;
- Background file: annual average background concentration of NO2, CO, PM10and O3 at background monitoring sites (Silva, 2008);
- Output: hourly average CO [mg/m^3], NO_2[µg/m^3],PM10[µg/m^3], C_6H_6, O_3[µg/m^3];

- Average speed: variable.

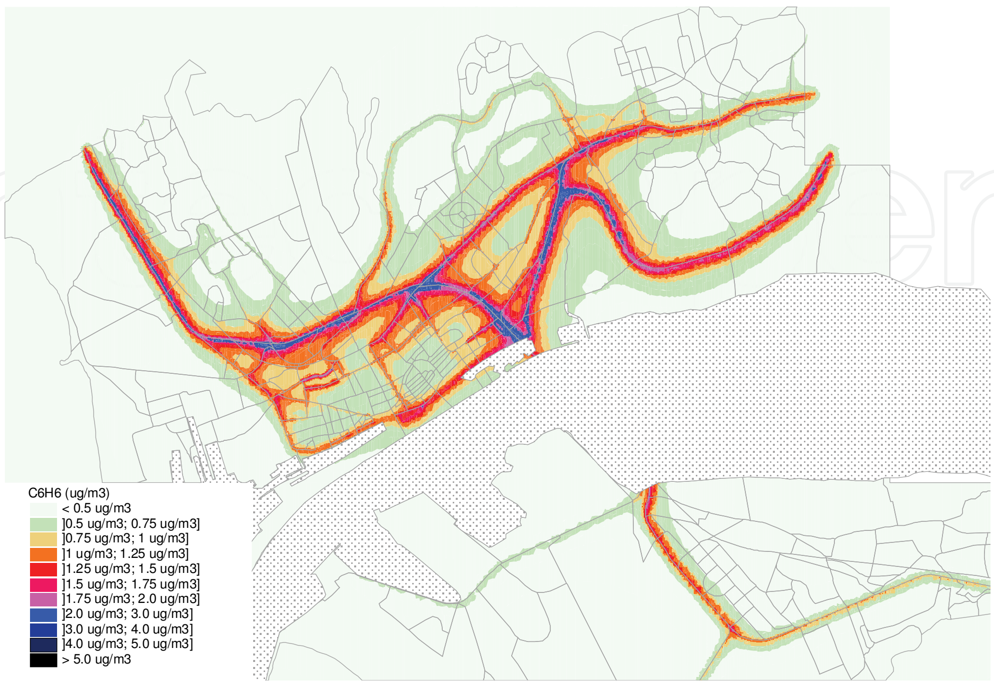
This article presents results for the summer scenario, the most critical (Figures 7a to 7e).



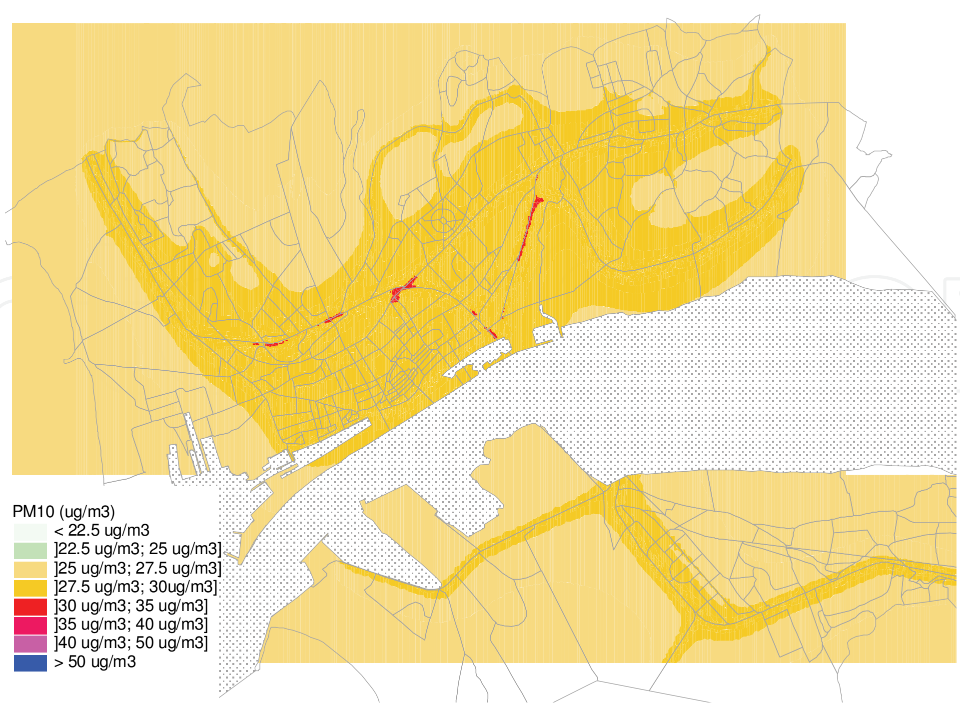
a) Carbon monoxide, CO



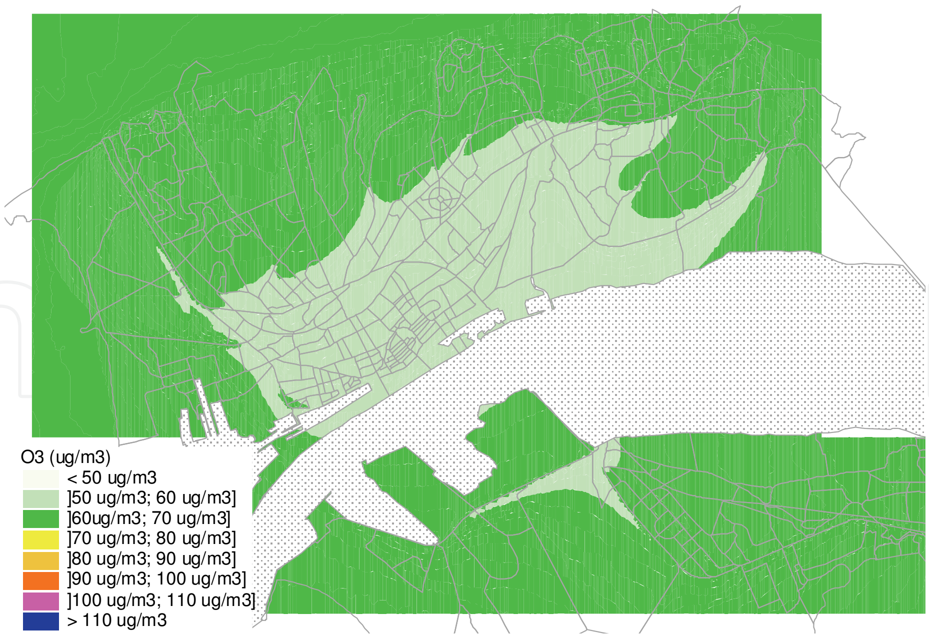
b) Nitrogen dioxide, NO_2



c) Benzene, C_6H_6



d) Particulate matter, PM10



c) Ozone, O_3

Fig. 7. Air pollution maps, summer scenario

4.4 CityAIR of Viana do Castelo

The combination of the concentration maps, according to eqn.(1), results in an overall air qualitymap (Fig. 8).

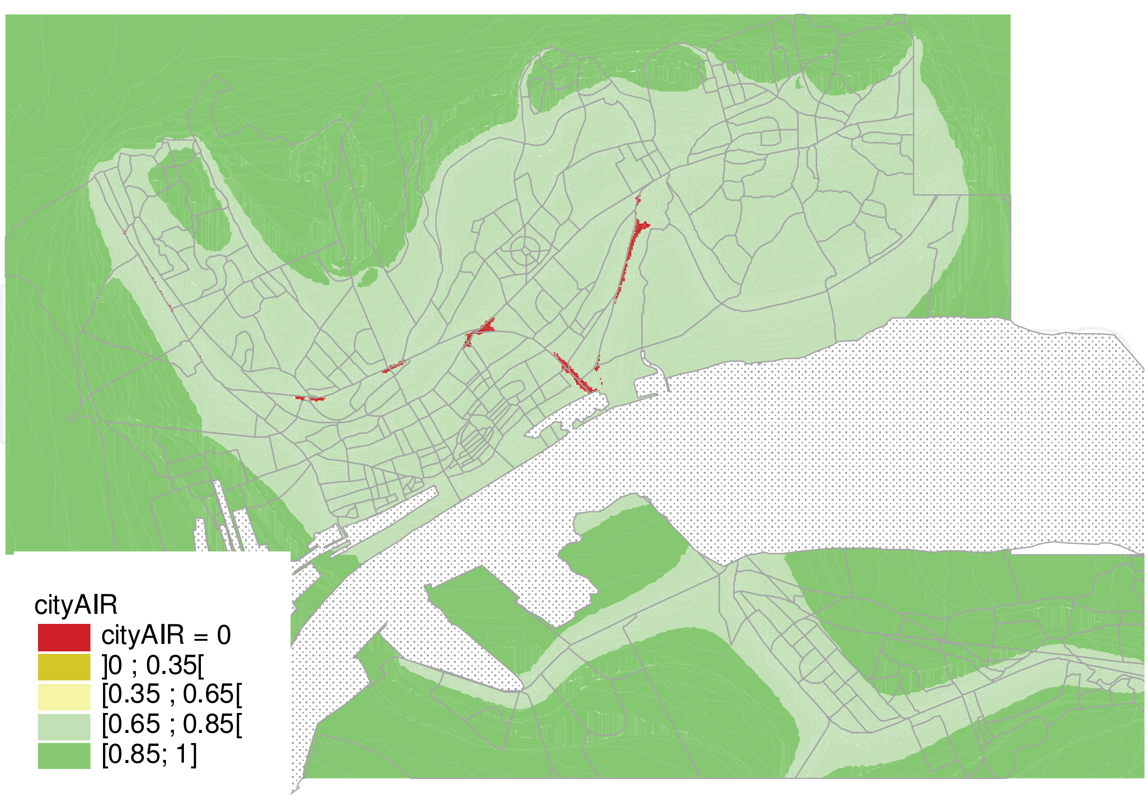


Fig. 8. CityAIR, summer scenario

Model results were overlain with a population GIS layer to estimate the affected population. Table 6 presents a synthesis of the areas and populations affected by air pollution in the city.

cityAIR	Population		Area	
	hab	%	m^2	%
= 0	69	0.2%	26332	0.2%
[0 ; 0.35[	0	0.0%	0	0.0%
[0.35 ; 0.65[	9	0.0%	3296	0.0%
[0.65; 0.85[	20477	71.7%	5152484	47.3%
[0.85; 1.0]	8002	28.0%	5711768	52.4%
Total	28557	100%	10893880	100%

Table 6. Areas and populations affected by air pollution

4.5 Analysis

The cityAIR index was developed to quantify city air quality. It depends on the concentrations of the five major urban pollutants: CO, NO_2, O_3, C_6H_6 and PM10. When none of the concentrations of these pollutants exceed the legal limit, cityAIR is calculated by combining the concentrations of different species. The cityAIR index is zero for areas with at least one pollutant concentration above the limit. Each area was also described as a binary data set, whereby a value of one signified that all concentrations were below the limit and a value of zero signified a threshold violation.

In combination with a Geographic Information System platform, the model and technologies used in this study proved to be useful for evaluating urban environmental quality, allowing the calculation of the areas and populations affected by air pollution in the city.

Although the inventory of air pollutant emission sources in the city of Viana do Castelo included one integrated pulp and paper mill, the road traffic sources made the greatest contribution to air pollution in the city. A dispersion model was used tocalculate air pollution in a continuous space of urban pollutant concentrations in the city. Horizontal maps were created for major air pollutants in urban areas (CO_2, C_6H_6, CO, NO_2, PM10 and O_3). The results demonstrated that the highest concentrations of primary air pollutants were in areas adjacent to the major roads. The obtained results are in agreement with field measurements and expected values. The highest pollutant concentrations were found in areas with a greater traffic flow or on roads with channel characteristics. Additionally, the weather conditions in the summer scenario were relatively unfavourable for dispersion and natural pollutant removal.

The cityAIR index defines air quality within a range from zero (poor air quality) to one (good air quality). Applying this model to the city of Viana do Castelo proved very useful for comparing the concentrations of major air pollutant species to their standards. This model generates a summary index of air quality that is easy to understand and intuitive for the general public.

Of the species studied, only NO_2 was found to be above legal limits. Air pollution maps reveal that the concentrations of PM10, NO_2, CO, CO_2 and C_6H_6 are higher in areas that are adjacent to high-traffic roads running through and around the city.

Because ozone is a secondary pollutant, its highest concentrations are not found near emission sources. Horizontal maps of O_3 show that the maximum ozone concentrations do not exceed the legal limit. However, in outlying areas, ozone concentrations reach the threshold for vegetation protection (65 µg/m3).

The distribution of the calculated cityAIR index over Viana do Castelo revealed that air quality is globally acceptable in this city (Figure 8). Nonetheless, the dearth of small zones on this map may be problematic. Small zones, including Av. 25 de Abril (the ramp to the bridge), the roundabouts of the hospital and football field and the access to the main road (IC1), have high levels of NO_2 over the legal limit.

Based on an analysis of the Table 6, we can conclude that only 0.2% of the population (69 pop.) in summer is exposed to a cityAIR index of zero, during which time 71.7% and 28.0% of the population benefit a cityAIR index of the population benefit a cityAIR index ranging between [0.65 ; 0.85[and above 0.85, respectively.

3. Conclusion

The urban air index used in Viana do Castelo, cityAIR, aggregates data for the air quality of a city and presents results in the context of standardised legal limits for air pollution.

Based on cityAIR, several priority areas for future mitigation and monitoring are proposed: Avenida 25 de Abril, Avenida Gaspar de Castro, access to west IC1 and access to north and south EN13.

When the results of this analysis were presented to the Municipality of Viana do Castelo cityAIR index proved to be easily understood and quite intuitive. For the problematic areas, a Monitoring & Mitigation Plan is being prepared.

In order to estimate pollutant emissions to the atmosphere from vehicular traffic, which is essential for evaluating both local and global air quality, emission factors were obtained for vehicles in Viana do Castelo and combined with the calculated vehicle circulation in that city. Thus, it is now generally possible to estimate the contribution of car traffic to climate change due to CO_2 emissions.

The model for air pollutant dispersion is consistent with field measurements. The model calculates concentrations of PM10, a component of secondary emission that originates under typical city conditions. The developed database of secondary particle concentrations in the city facilitates simulations of PM10 concentrations.

The cityAIR index developed here is transparent, simple and easy to understand. Indicator weights and dimensions used in the cityAIR calculation depend on the control points defined during the normalisation process. A variety of options can be used during the cityAIR calculation to focus index results on different dimensions and indicators of overall urban environmental quality.

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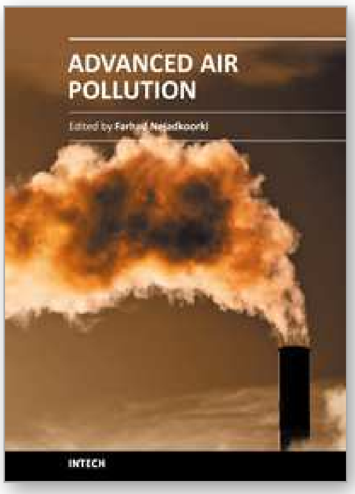

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Leading air quality professionals describe different aspects of air pollution. The book presents information on four broad areas of interest in the air pollution field; the air pollution monitoring; air quality modeling; the GIS techniques to manage air quality; the new approaches to manage air quality. This book fulfills the need on the latest concepts of air pollution science and provides comprehensive information on all relevant components relating to air pollution issues in urban areas and industries. The book is suitable for a variety of scientists who wish to follow application of the theory in practice in air pollution. Known for its broad case studies, the book emphasizes an insightful of the connection between sources and control of air pollution, rather than being a simple manual on the subject.