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Implication of Secondary Atmospheric Pollutants in the Air Quality: A Case-Study for Ozone

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Abstract

Air quality and Public Health are concepts linked to each other. Within the frame of Public Health, a wide range of external factors, derived from rising wastes towards all environmental compartments, may generate harmful effects on human health. In particular, the release of polluting compounds into the ambient air coming from emission sources is a paramount concern, given that atmospheric pollution is considered the most significant environmental risk for human beings. In this context, while this chapter to provide an overview of the most critical air pollutants that can depict air quality status in terms of exposure, potential effects, emission sources, and types of pollutants, the principal purpose is focused on secondary atmospheric pollutants, emphasizing to tropospheric ozone as a significant pollutant within this group. In this sense, aspects such as the atmospheric ozone chemistry responsible for its formation and its spatial distribution into vast territories, including urban, suburban, and rural environments, were conveniently explained. Based on displayed evidence, primaries air pollutants, mainly nitrogen oxides, volatile organic compounds, and carbon monoxide, are responsible for the tropospheric ozone's formation; therefore, reducing their levels could be translated into a decrease of ozone concentrations at the ground-level. Attending to the ozone distribution, the revealed findings lead to the next concentration gradient: higher ozone levels in rural, followed by suburban and urban sites, respectively. Finally, it can be concluded that the importance of tropospheric ozone within air quality lies in the possibility of producing harmful effects on human health and generating climate changes, either directly or indirectly.

Keywords: air quality, atmospheric pollution, emission sources, secondary polluting compounds, tropospheric ozone's chemistry, and importance of ozone within air quality frame

1. Introduction

The human being's health is regulated by different agents, such as adequate alimentation, appropriate sanitation and hygiene, safe workplaces, and sustainable cities, among others. In this sense, environmental health points to be one of the most relevant factors influencing human beings' well-being, given the existing direct relationship between human beings and the surrounding environment. Therefore, both variables (environment and human being) should keep an equilibrium.

Nevertheless, within that binomial, human activities can negatively affect the whole environment generating environmental variations at the contamination level, or climate change, at the global level [1–3]. As a consequence, a deteriorated environment can seriously affect the human being's health.

In this sense, the population growth featured over the last decades has been translated into a fast industrial grown, an increment of transportation networks and energy demands, generating a negative effect on the different environmental departments due to rising wastes [4]. In particular, the rise of polluting emissions into the atmosphere leads to a decrease in air quality, thereby becoming a public health issue. In fact, atmospheric pollution is considered the major environmental risk to human being's health worldwide [5].

According to Landy (see [6]), atmospheric pollution is defined as the presence in the air of one or more contaminants in such a concentration and of such duration as causing a nuisance or being injurious to human life, animal life, or vegetation. Therefore, atmospheric pollution and air quality are intimately linked, so a lower level of atmospheric pollution carries a higher air quality and vice versa.

Atmospheric pollution covers a wide variety of pollutants, such as gaseous compounds (organic and inorganic chemicals) and airborne particulate matter. The pollutants used as air quality indicators are defined as "criteria air pollutants" [see https://www.environment.gov.au/protection/air-quality/air-pollutants, accessed October 28, 2020], and they are described as coming. So, polluting species as nitrogen oxides (NO_x), sulfur oxides (SO_2), carbon monoxide (CO), ozone (O_3), particulate matter (PM), and lead (Pb) are air pollutants commonly found in urban environments. In the case of nitrogen oxides, the most paramount compounds at the atmospheric level point to nitrogen monoxide (NO) and nitrogen dioxide (NO_2). In ambient air, NO is a highly unstable molecule rapidly oxidizing in the presence of oxygen, yielding nitrogen dioxide; therefore, they sustain a direct chemistry relationship. For this motive, NO is also considered a free radical [7]. NO_2 is a gaseous reddish-brown compound, toxic and irritating. It has a characteristic pungent odor and is a strong oxidant, and reacts with water to produce nitric acid (HNO_3). While at the high ambient NO concentrations, this oxidation reaction is based on the oxygen (O_2) presence [8], at the low levels, the molecular O_3 is responsible for oxidizing, within minutes, NO molecule [9]. SO_2 is a dense and colorless gas with a suffocating odor that readily soluble in water. Its oxidation generates the formation of sulfuric acid (H_2SO_4) by reacting with the surface of particles in the presence of metallic catalysts [10]. CO is a colorless, odorless, and tasteless gas, poorly soluble in water, and it has a slightly lower density than air [11]. O_3 is one of the most potent oxidizing agents due to its high redox potential. It is an essential constituent of the upper atmosphere [12]. Relative to the PM, it is needed to indicate that these pollutants are characterized in function on its equivalent aerodynamic diameter (EAD). It is a method for classifying PM [13]. At the atmospheric level, the most studied particles aimed at $PM_{2.5}$ (EAD of 2.5 μm or less) and PM_{10} particles (EAD $\leq$ 10 μm). As a general concept, atmospheric particulate matter consists of a complex mixture formed by solid and liquid organic and inorganic origin substances suspended in the air. Therefore, the particle composition can differ in distinct variables, such as emission sources and meteorological features affecting a specific location. Finally, Pb is a toxic tometal, and it is associated with particulate matter in ambient air [14].

At the atmospheric level, a broad and important group of polluting agents are included within the volatile organic compounds' family (VOC's). Benzene (C_6H_6) is considered the major COV's with particular attention to urban environments. It is a highly volatile compound, and it is degraded rapidly in the upper atmosphere. Given its solubility in water, the atmospheric benzene can be deposited on surface

waters and soil due to rain action, removing a minor amount of air benzene [https://www.who.int/ipcs/features/benzene.pdf, accessed November 9, 2020].

The ambient air's target pollutant levels will depend on geographic area, topographic, emission sources, and meteorological variables. Air pollutants' occurrence is directly related to release processes from emission sources and their formation through chemical reactions between several pollutants under specific meteorological conditions.

Firstly, this work pretends to introduce an overview concerning air quality in terms of exposure to air pollutants, types of contaminants, and emission sources. Within this frame, an essential aspect of the air quality is supported by the secondary atmospheric pollutants. In this sense, on the other hand, this work aims to display the importance of this type of compounds, focused mainly on ozone.

2. Exposure to air pollutants on human being and potential effects on health

Numerous scientific studies have revealed a direct relationship between exposure to poor air quality and the appearance of harmful effects on human health [15–17]. Broadly, long and short-term exposures to toxicant compounds suspended into the air may yield different toxicological impacts on humans, such as cardiovascular and respiratory diseases, eyes and skin irritation, and chronic illness, among others.

Exposure to air pollutants on the human being depends on both the target air pollutant's concentration, usually expressed in $\mu g/m^3$ and the exposure time to that polluting level with a unit in minutes. There are different air pollutant exposure models (APEX). The scientific community has widely described APEX [18–20]. They are based on probabilistic analysis simulating different exposure environments using several study variables, such as population data, activities developed by people, traffic density, meteorological features, emission air pollutant data, potential fixed and mobile emission sources [https://www.epa.gov/sites/production/files/2019-11/documents/apex5_introduction_document.pdf, accessed November 13, 2020].

Given the considerable number of polluting compounds existing in the atmosphere, a brief review relative to potential effects of criteria air pollutants (further COV's) on human being's health is addressed.

2.1 Nitrogen oxides

Exposure to nitrogen oxides may raise the risk of respiratory infections [21], such as burning eyes, sore throat, or cough [22]. Exposure to levels ranged between 1300 and 3800 $\mu g/m^3$ (0.7–2.0 ppm, parts of million) for 10 min may increase the inspiratory and expiratory flow resistance [8].

2.2 Sulfur oxide

Sulfur dioxide produces an extensive glossary of harmful effects on human health. The most likely results point to wheezing, shortness of breath, and chest tightness, which are intensified during physical activity development. According to the American Environmental Pollution Agency [23], an increase in respiratory symptoms and a lung ability reduction due to durable exposures at high sulfur dioxide levels may be produced. Similarly, it has been linked to cardiovascular disease [24].

2.3 Carbon monoxide

The symptoms derived from carbon monoxide exposure are not always obvious. Once inhaled, CO readily reacts with existing hemoglobin in the blood, which is the protein responsible for the transport of O_2 in blood [25], reducing the blood's oxygen-carrying capacity [26]. Carbon monoxide has a greater affinity for hemoglobin than oxygen (>200 times, approximately) [27]. The amount of hemoglobin that has been reacted with CO is named carboxyhemoglobin [28].

At low concentrations, the most common symptom results in a headache. However, other effects, like dizziness, feeling and being sick, tiredness and confusion, stomach pain, shortness of breath, and difficulty breathing, are willing to appear [29]. Finally, the inhalation of carbon monoxide at high concentrations is lethal [30].

2.4 Ozone

In the function of the exposure concentration, the effects occasioned by ozone inhalation can be classified as acute and chronic. The first group embraces inflammatory mediators' alterations, morbidity, and mortality, while the second points to lung function reduction, atherosclerosis and asthma development, and reduction in life expectancy [31].

2.5 Airborne particulate matter

The major effects of atmospheric particles on human being's health appear in the cardiovascular system due to the mechanisms of systemic inflammation, direct and indirect coagulation activation, and direct translocation into the systemic circulation [32]. Similarly, scientific evidence shows that ozone exposure exacerbates respiratory diseases. The inhalation of particulate matter produces oxidative stress and inflammation, leading to pulmonary anatomic and physiologic remodeling [33].

2.6 Lead

Exposure to Pb may affect adults, children, and unborn babies' health. It is stored in bones and teeth, even damaging different body parts like the liver, kidneys, and brain. Pb circulates in blood once into the body. The levels of Pb in blood express micrograms of Pb per deciliter of blood [34]. Pb's intoxication may drive to the next symptoms: abdominal pain, anemia, constipation, headaches, irritability, loss of concentration and memory, and sleep disorders [35].

2.7 Volatile organic compounds

Broadly, inhaled volatile organic compounds are associated with oxidative stress and decreased lung function [36]. In the case of benzene, since 1987, it has been included in group 1 of the IARC carcinogenic classification system [37].

Through the International Programme on Chemical Safety, World Health Organization has developed a series of documents concerning "Environmental Health Criteria, EHC" (more than 200 issues). While these EHC encompass for each studied air pollutant different aspects relative to emission sources, atmospheric levels, among others, any reader interested in delving into subjects regarding the effects of air pollutants on human health can access the next link: https://www.who.int/ipcs/publications/ehc/ehc_numerical/en/, accessed November 13, 2020.

Finally, it is relevant to highlight Public Administrations's growing interest in controlling and assessing toxicant compounds in ambient air to protect human being's health. Within this frame, the European Union has developed Air Quality Standards for setting limit or target values for several air pollutants. Directive 2008/50/EC (see [38]) lays down the following limit values: 40 $\mu g/m^3$ for NO_2 and PM_{10}, 5 $\mu g/m^3$ for C_6H_6, 0,5 $\mu g/m^3$ for Pb as calendar year averages, 10 mg/m^3 for CO as maximum daily eight-hour mean and 125 $\mu g/m^3$ as one-day average (not to be exceeded more than three times a calendar year).

3. Emission sources of air pollutants

3.1 Natural sources

Firstly, natural emission sources of air pollutants do not depend on human activity. They mainly characterize the occurrence of polluting agents into the atmosphere at the local scope. Among others, it is worth mentioning as natural origins of air pollutants, forest fires, dust storms, volcanos, emissions from the water surface, microbial activity, and anaerobic degradation of organic material in terrestrial environments.

Natural sources' contribution to air pollutants' presence in ambient air is lower quantitatively than that produced by anthropogenic sources.

3.2 Anthropogenic sources

Anthropogenic emission sources result from human activity. Therefore, large urban areas support highly-polluting emissions into the ambient air due to many emission focus (road traffic, heating house, and industry, mainly), which generates relevant health issues.

Dominant emission air pollutant sources derived from human activity are:

- Fuel combustion from motor vehicles

- Power generation

- Industrial activities

- Municipal and agricultural waste sites as well as its incineration/burning

- Residential cooking/heating, and lighting with polluting fuels (https://www.who.int/airpollution/ambient/pollutants/en/, accessed November 16, 2020)

4. Types of pollutants

At the scientific level, there are several categories of classifying air pollutants. So, they can be ranked in terms of the type of emission source (primary or secondary pollutant), chemical composition (gaseous agents or particulate matter), place of release into the atmosphere (indoor or outdoor site) [39]. This section will encompass their possible origin in emission sources' function within this work's common thread.

4.1 Primary pollutants

Primary polluting compounds involve those pollutants that are directly emitted into the atmosphere. Their origin can be natural (for example, volcanos or grassland fires) and anthropogenic (industrial and vehicular emissions).

4.2 Secondary pollutants

Secondary air pollutants are not generated from emission sources, but they need at least two primary pollutants to react with each other to yield a secondary agent [40].

Based on the previous description, NO_x, SO_2, CO, PM are examples of primary air pollutants, whereas O_3 and peroxyacylnitrates (such as peroxyacetylnitrate, peroxy-propionyl nitrate, and peroxybenzoylnitrate) are secondary pollutants.

5. Ozone

5.1 Description

The ozone is a powerful oxidant agent capable of oxidizing organic compounds and a precursor to yield hydroxyl radicals [41]. Only fluorine, oxygen fluoride, and atomic oxygen have a higher redox potential than O_3. It is formed by three oxygen atoms and is a greenhouse gas [42]. While ozone is a constituent of the Earth's upper atmosphere (stratosphere) [43], exceeding 1000 parts per billion (ppb) concentrations [44], it also occurs at ground-level (troposphere) [45]. Ground-level O_3 concentrations rise with the height from 20 to 200 ppb depending on proximity to primary air pollutants emission sources [46].

On the one hand, O_3 is beneficial when it is found in the atmosphere's upper layer, given that it forms a protective coating for human beings against ultraviolet solar radiation [47]. Nevertheless, high levels of tropospheric O_3 (at the ground-level) may produce human health's harmful effects due to its high oxidant capacity [48], which appoints this compound as the most significant photochemical pollutant [49].

5.2 Ozone atmospheric chemical: formation at the tropospheric level
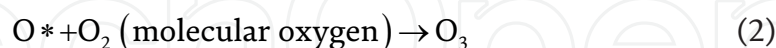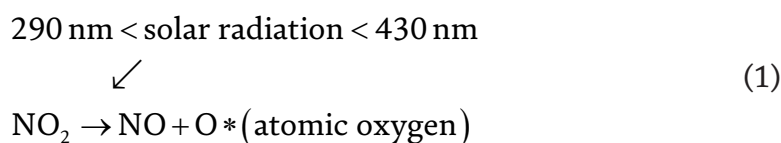
Given that the ozone is cataloged as a secondary air pollutant, its occurrence into the ambient air is due to chemical reactions among primary polluting compounds emitted directly from emission sources. Therefore, its tropospheric formation is associated with anthropogenic and biogenic emissions [50]. Reactions ruling ground-level ozone generation have been vehemence studied over past decades [51].

The essential primaries pollutants involved in yielding tropospheric ozone are NO_x (NO and NO_2), COVs and CO. Solar radiation is a primordial agent for ground-level ozone formation.

In the case of NO_x, once NO is released from emission sources into the atmosphere, this is oxidized to generate NO_2. The formation rate of this reaction is highly dependent on the ambient NO concentration. While high NO levels lead to a fast conversion to NO_2, low levels slow down its production rate.
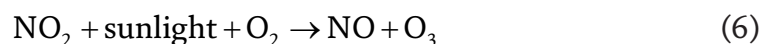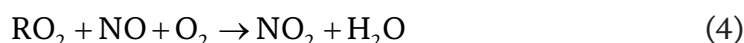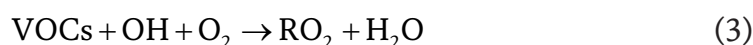
Although the oxidative NO reaction's predominant oxidant agent is O_3, molecular oxygen can also ease its conversion to NO_2.

A fraction of the generated NO_2 undergoes conversion to NO during diurnal hours due to a photolysis process. This re-conversion is translated into yielding tropospheric O_3, according to Eqs. (1) and (2) [52].
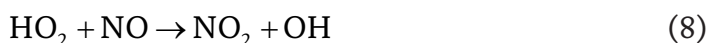
$$290\,nm < solar\ radiation < 430\,nm$$
$$\swarrow \qquad\qquad (1)$$
$$NO_2 \rightarrow NO + O*(atomic\ oxygen)$$

$$O* + O_2\,(molecular\ oxygen) \rightarrow O_3 \qquad\qquad (2)$$

A minimum ambient air NO_2 concentration (0.02–0.03 ppb) is required for generating O_3.

Relative to VOCs, the oxidation of these polluting compounds yields ground-level O_3. At the atmospheric level, this oxidative reaction is carried out in the presence of NO_x and sunlight [53]. The chemistry reactions responsible for the tropospheric O_3 generation from VOC's are shown in Equations from 3 to 6 [54].

$$VOCs + OH + O_2 \rightarrow RO_2 + H_2O \qquad\qquad (3)$$

$$RO_2 + NO + O_2 \rightarrow NO_2 + H_2O \qquad\qquad (4)$$

$$H_2O + NO \rightarrow NO_2 + OH \qquad\qquad (5)$$

$$NO_2 + sunlight + O_2 \rightarrow NO + O_3 \qquad\qquad (6)$$

Therefore, the VOCs oxidation is regulated by hydroxyl radicals (OH), oxygen, and NO_x.

Finally, the oxidative CO process drives the formation of hydroperoxyl radical (HO_2), which reacts with atmospheric NO for yielding NO_2, according to Eqs. (7) and (8) [55]. The generation of ground-level O_3 from NO_2 oxidation has already been explained previously.

$$CO + OH \rightarrow CO_2 + HO_2 \qquad\qquad (7)$$

$$HO_2 + NO \rightarrow NO_2 + OH \qquad\qquad (8)$$

At the European level, the highest tropospheric ozone is located on the Mediterranean coast (see **Figure 1**). According to the chemical formation of ground-level O_3, preventive measures driving toward abatement of NO_x, VOCs, and CO concentrations in ambient air would assist control of tropospheric O_3 levels.

It is relevant to highlight that the participation of ground-level O_3 in the atmospheric chemistry generates free radicals, such as hydroxyl radical (OH^*) [56], which governs the atmospheric lifetime of many species and their potential to contribute to climate change.
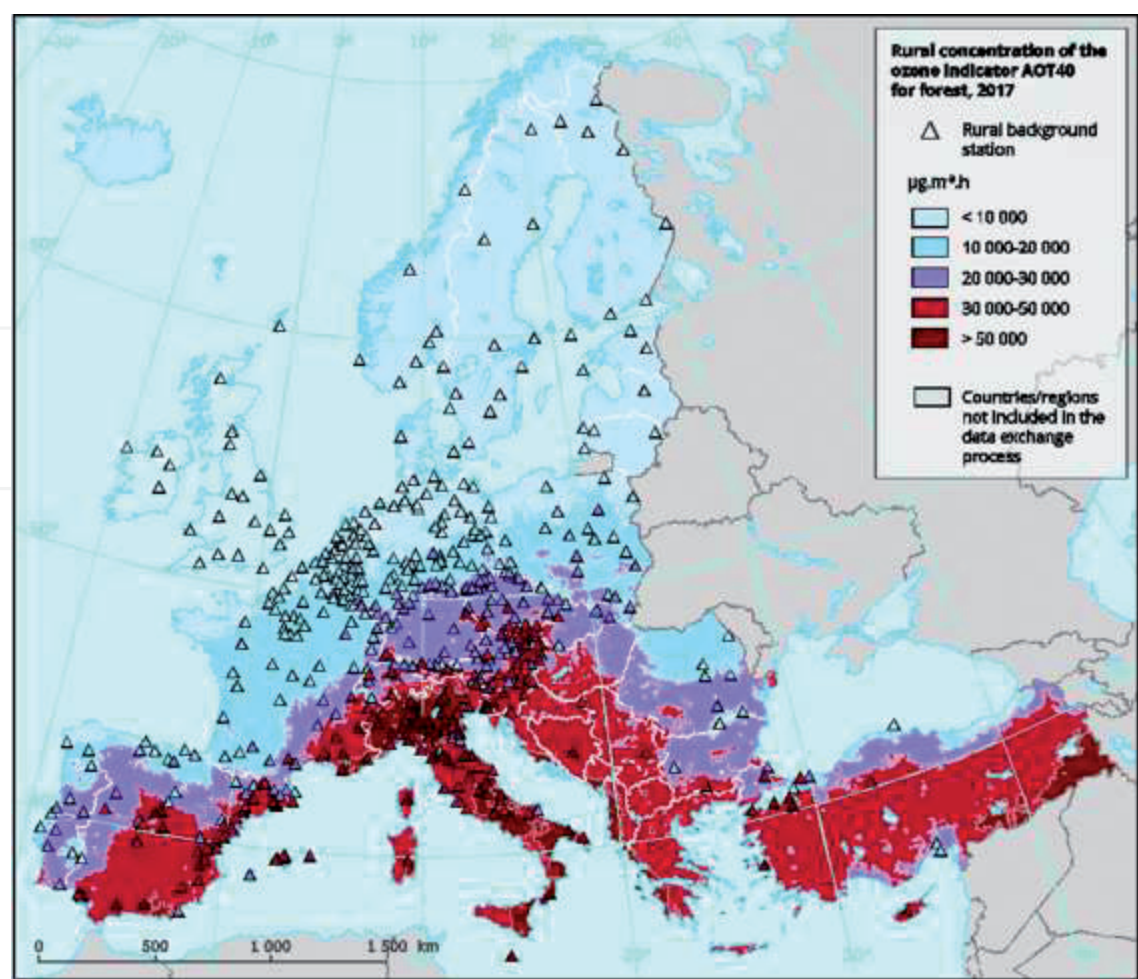
Figure 1.
Accumulated ozone exposure values for forest — over a threshold of 40 parts per billion (AOT40f) — for 2017, as calculated for the fusion maps and as measured at rural background stations. Source: European Environment Agency (Available at: https://www.eea.europa.eu/data-and-maps/figures/rural-concentration-of-the-ozone-5, accessed 18 November 2020).

5.3 Measurement techniques

Currently, there are several methodologies for measuring tropospheric O_3. Broadly, they can be classified into two clusters: (i) Those methods needing a sampling process and an ulterior analysis into the laboratory, and (ii) those methods measuring in real-time, collecting and determining the tropospheric O_3 levels in situ (at the target sampling point). Whereas in the first case, they are defined as passive methodology, in the second case, active methods.

5.3.1 Passive methodology

Passive sampling methods are valuable instruments for air pollution monitoring. They support ground-level O_3 measures' simultaneous performance at numerous sampling points, which results in remarkable relevance. Their implementation on an extensive study surface would picture spatial distribution concerning O_3 levels within that domain. Characteristics such as small, simple, lightweight instrumentation, low-cost, and minimum maintenance give it advantageous features against active methodology.

Fick's First Law, which postulates a mass transfer phenomenon through a layer of gas or a membrane, can explain the sampling process. It is based on a concentration gradient process, relating the flow of target gas that diffuses from regions of high

concentration to regions of low concentration with the exposure time and the area of the passive sampler [57].

The gas collection is based on ozone's chemical reactions with a specific reagent for generating a final product, which is determined in the laboratory using appropriate analytical techniques [58].

Within this methodology, two types of samplers are available commercially: Radiello and Ogawa sampler, respectively. Radiello type sampler sustains a radial diffusion (the diffusive process occurs in all space directions), whereas Ogawa only supports an axial diffusion.

Suppose any reader needs more information about Radiello or Ogawa sampler. In this case, this one can be satisfied in the following links: https://www.restek.com/pdfs/radiello-manual.pdf for Radiello sampler and http://ogawausa.com/wp-content/uploads/2014/04/proozone.pdf for Ogawa sampler (both they were accessed November 19, 2020).

The spectrophotometric analysis is usually used for determining the formation of products generated by collecting ozone using passive samplers. This technique is based on colorimetric processes.

5.3.2 Active methodology

The traditional methods for monitoring ground-level ozone have been the automatic methods in continuous. Those methods are based on the direct measure of a pollutant in the air matrix. In the case particular of O_3, there are two specific methods:

- Chemiluminescence in the gas phase. It is based on photons' detection produced in the exothermic reaction between O_3 and ethene or nitrogen oxide [59].

  The chemiluminescent light emission's intensity (from 350 to 550 nm) is proportional to the ozone concentration in ambient air. This method is appropriate for O_3 measures into the concentration range from 0.001 to 100 ppm, obtaining a linear response. It does not have known interferences, and its response time is 1 sec, reaching up to 2% accuracy at 50 ppb ozone [60].

- Ultraviolet photometric. It is based on absorption that the molecular O_3 presents in the spectrum's ultraviolet region, whose maximum is situated highly close to the mercury emission line at 254 nm [61]. The instruments based on that technique evaluate O_3 levels from the existing relationship between the sequentially transmitted light intensities at 253.7 nm. The ultraviolet photometric is a more stable method than the chemiluminescence. However, it has a response time significantly higher (30 sec). Similarly, it can present interferences with carbonyl or aromatic compounds that absorb in the same UV region.

5.4 Ozone levels in the ambient air

The tropospheric O_3 concentrations are usually expressed at ppb or µg/m^3 (mass per unit volume). The conversion factor between both units depends on pollutant type (in this case, molecular O_3), ambient air temperature, and pressure, according to Eq. (9).

$$\mu g / m^3 = ppb * \frac{\text{molecular weight}}{\text{molecular volume (liters)}} \quad (9)$$

Where

$$\text{molecular volume} = 22.4\,\text{L} * \frac{\text{absolute temperature}\,(\text{k})}{273.15\,\text{k}} * \frac{1013.25\,\text{hPa}}{\text{atmospheric pressure}\,(\text{hPa})}$$

For tropospheric O_3, in order to transform ppb to µg/m^3, a conversion factor of 2.142, 2.066, and 1.962 should be used (conversion make to 0, 10, and 25°C, respectively) (http://www.apis.ac.uk/unit-conversion, accessed November 23, 2020).

A relevant research study used data monitored by several countries' air quality monitoring networks for reporting tropospheric O_3 patterns [62]. Those O_3 data grouped 808 urban and 300 rural fixed stations. In the urban environments, the reached findings reported annual mean values of daily O_3 concentrations ranged from 19.5 ppb in the United Kingdom to 27.2 ppb in the United States during the studied period, while in South Europe Region (Italy, France, and Spain), the levels were next to 24 ppb. The lowest O_3 concentrations occurred on weekdays, whereas
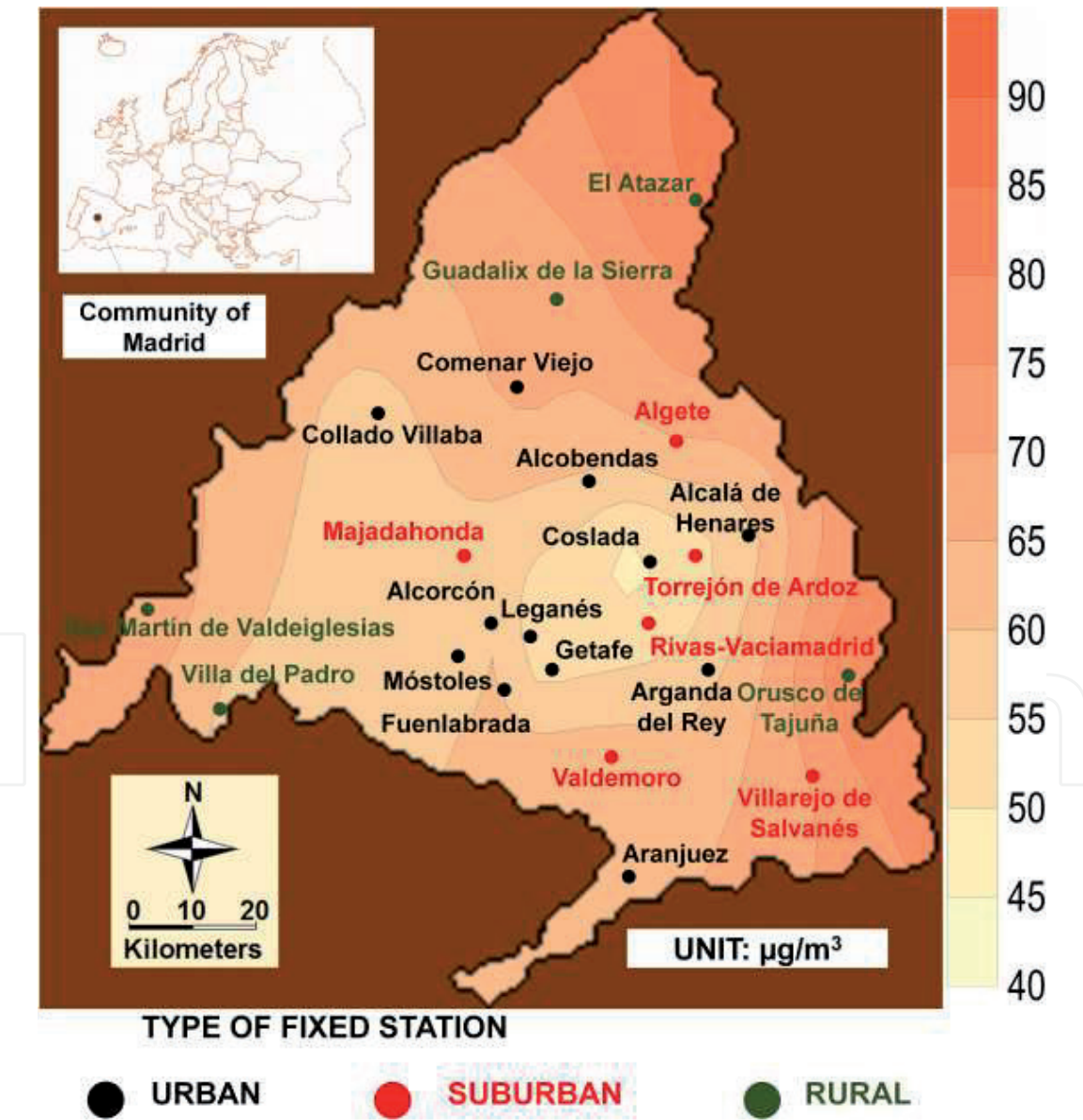

Figure 2.
Spatial distribution of the annual average O_3 concentrations within the Community of Madrid (2018). Source: Own elaboration using O_3 data monitored in 2018 and obtained from Community of Madrid's open-access database (https://www.comunidad.madrid/, accessed 20 November 2020).

those highest ones were found during weekends. On Monday, the daily mean O_3 concentrations were 1.4–3.8% higher than on other weekdays.

In rural environments, higher tropospheric O_3 concentrations than at urban sites were exhibited. The annual daily mean O_3 concentrations ranged between 28.5 ppb in the United Kingdom to 36.8 ppb in Japan over the investigated time. The O_3 concentrations between weekdays and weekends showed high stability (differences lower than 1 ppb).

While the highest levels of primary air pollutants are found in urban areas, given that their dominant emission sources are within these zones, the highest O_3 concentrations are pointed in semi-urban and rural environments, according to its tropospheric chemistry. The major reason sustaining this behavior is that tropospheric O_3 acts secondary pollutant, which needs a particular time for its formation in ambient air, displaced an absolute distance during that time concerning the prevalent emission primary source.

Ground-level O_3 data monitoring at 23 fixed stations from the Community of Madrid's air quality monitoring network during 2018 was used for picturing concentration gradient along all studied surface in order to knowledge the spatial distribution of tropospheric ozone into a typical South Europe Region. Community of Madrid is located in the center of Iberian Peninsula, it has a population of over 6,500,000 inhabitants, and it consists of 179 municipalities. The iso-concentration map of annual average O_3 levels in the Community of Madrid in 2018 was built by using a Geographic Information System. The concentrations at the not measured monitoring points were extrapolated from measurement points using the Kriging method as a geostatistical estimation tool [63].

Figure 2 shows spatial variation within the Community of Madrid's territory. As can be seen, higher annual O_3 concentrations at rural sites than suburban and urban areas were averaged during 2018, reaching a value of 70.8, 60.5, and 57.5 $\mu g/m^3$ at rural, suburban, and urban sites, respectively; therefore, higher levels were represented away from the emission sources for primary air pollutants, such as NO, NO_2, CO, C_6H_6, SO_2, and particulate matter.

It is necessary to highlight that the annual O_3 typical average in cities reaches values between 20 and 30 ppb [64]. In the previous case study, the annual average concentration of O_3 in urban areas fell into the indicated range (29.31 ppb, it expressed to 25°C temperature and 1013.25 hPa pressure).

5.5 Current legislation

Over the last decades, the Public Administrations have shown a growing interest in environmental issues, particularly toward the air quality, rising the air pollutants

Objective	Averaging time	Target Value
Human health's protection	Maximum daily eight-hour mean	120 µg/m3 not to be exceeded on more than 25 days per civil year averaged over three years
Vegetation's protection	From May to July	AOT40 (calculated from 1 h values) 18 000 µg/m3 • h averaged over five years

AOT40 indicates the sum of the difference between hourly concentrations greater than 80 µg/m³ and 80 µg/m³ over a given period using one-hour values monitored from 8.00 a.p. to 20.00 p.m.

Table 1.
Target values relative to ground-level O_3.

control by implementing Air Quality Standards to reduce human beings' exposure to atmospheric polluting.

In this sense, European Union developed Directive 2008/50/CE [38] for setting air quality objectives in order to reduce harmful effects on human health and the environment. In the case of tropospheric O_3, the Directive lays down data quality objectives for measurements ambient air ground-level O_3 (it sets a measurement uncertainty of 15% for fixed measurements, with a minimum capture of data of 90% (during summer) and 75% (winter), as well as target values (see **Table 1**).

In this context, the Member States establish air quality monitoring networks (AQMNs) in their territories for testing compliance with those air quality objectives. In order to constitute an AQMN, the Directive 2008/50/EC sets criteria concerning classification, location, and a minimum number of sampling points. Nevertheless, aspects relative to each fixed station's representativeness within AQMN in a concrete area are not evaluated, which can be considered a limitation of the Air Quality Standard. As a consequence, it does not exist a harmonized methodology allowing assess the fixed stations' representativeness. Therefore, this issue should be addressed in terms of air quality management.

6. Consultation sites

In order to further deeper in Sections exhibiting formation and levels of ozone, the next links are displayed:

Chemistry formation of ozone.

https://earthobservatory.nasa.gov/features/ChemistrySunlight/chemistry_sunlight3.php (accessed November 12, 2020).

http://ozone.meteo.be/meteo/view/en/1547746-Formation+of+ozone.html (accessed November 23, 2020).

Levels of tropospheric ozone.

https://pubmed.ncbi.nlm.nih.gov/ (accessed October 29, 2020).

https://www.sciencedirect.com/ (accessed November 3, 2020).

In the two last databases, the Keywords for searching scientific documents involving O_3 levels are: (O_3 or ozone) & (ground-level or tropospheric) & (ambient air).

7. Importance of presence of ground-level ozone in air quality

Based on the previously reported information, tropospheric ozone is a highly reactive air pollutant. For this reason, it plays a crucial role in the ground-level atmospheric chemistry, given that its participation generates free radicals. At the health level, these last compounds are responsible for forming other ones that can induce potential human health's adverse effects, for example, pollutants driving acid rain or those implicated in deposition processes.

Therefore, tropospheric ozone is responsible for the emergence of harmful effects on human health in direct (by itself) and indirect ways (through the generation of other toxic compounds).

On the other hand, at the climate level, the tropospheric O_3 is a greenhouse gas that may produce climate changes by itself or by forming other air pollutants.

Given that its occurrence in ambient air depends on both the presence of other primaries atmospheric pollutants and meteorological conditions, Public Health's preventive measures focused on human health's protection and climate change

should be implemented in terms of assessing air quality and executing air quality plans in order to reduce primaries atmospheric pollutant levels.

8. Conclusions

Air quality and human health are concepts associated with each other, given that good air quality influences adequate life quality in terms of health and well-being, and vice-versa.

Nevertheless, an increase of polluting emissions into the atmosphere due to growing industrial activities and rising private and public transport networks, among others, threatens clean air quality.

In this sense, responsibility administrations set criteria for evaluating the air quality in order to reduce human exposure to airborne pollutants. Within this context, the European Union lays down Air Quality Standards involving air quality objectives, such as limit and target values. According to these guidelines, Member States sustain air quality monitoring networks into their territories to assess the air quality and test the compliance with those air quality objectives.

The presence and pollutants' chemical composition scattered into the ambient air is tremendously heterogeneous, which difficulties the air quality assessment. Among pollutants compendium presents in the air, primaries and secondary compounds are found.

Knowledge of secondary's air pollutants is fundamental to elucidate their importance within the air quality frame. In particular, the ozone encompasses relevant aspects, given its high reactivity, in terms of (i) health and (ii) climate.

Tropospheric ozone plays a critical role within both items, either directly or indirectly. It is able to induce adverse effects on humans at the health level, as changes in climate. Both effects could be generated by ground-level ozone itself or by participating in the formation of other air pollutants with the capability of producing these effects.

It is generated from primary air pollutants, for what is displaced to zones where there are not prevailing emission sources for primary air pollutants. In this sense, the highest tropospheric O_3 levels are found in rural environments instead of suburban and urban zones (typical of primary air pollutants).

As a remark conclusion, attending to the ambient O_3 formation, control measures on emission sources of primaries air pollutants should be implemented in order to abate the potential tropospheric O_3 effects on health and climate.

Conflict of interest

The author declares no conflict of interest. This work does not have commercial purposes, only scientific ones.

Other declarations

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