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Short Communication

# Assessing nitrogen dioxide ($NO_2$) levels as a contributing factor to coronavirus (COVID-19) fatality

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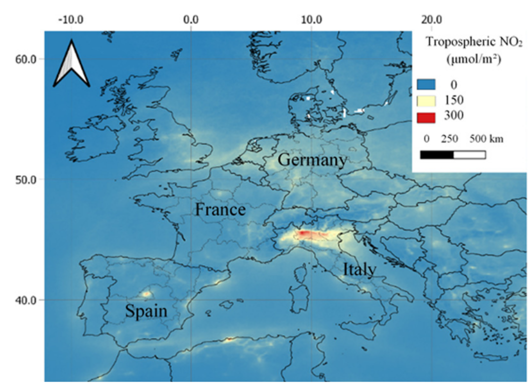
## GRAPHICAL ABSTRACT

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## ABSTRACT

Nitrogen dioxide ($NO_2$) is an ambient trace-gas result of both natural and anthropogenic processes. Long-term exposure to $NO_2$ may cause a wide spectrum of severe health problems such as hypertension, diabetes, heart and cardiovascular diseases and even death. The objective of this study is to examine the relationship between long-term exposure to $NO_2$ and coronavirus fatality. The Sentinel-5P is used for mapping the tropospheric $NO_2$ distribution and the NCEP/NCAR reanalysis for evaluating the atmospheric capability to disperse the pollution. The spatial analysis has been conducted on a regional scale and combined with the number of death cases taken from 66 administrative regions in Italy, Spain, France and Germany. Results show that out of the 4443 fatality cases, 3487 (78%) were in five regions located in north Italy and central Spain. Additionally, the same five regions show the highest $NO_2$ concentrations combined with downwards airflow which prevent an efficient dispersion of air pollution. These results indicate that the long-term exposure to this pollutant may be one of the most important contributors to fatality caused by the COVID-19 virus in these regions and maybe across the whole world.



## 1. Introduction

The outbreak of the novel coronavirus (COVID-19) is an ongoing global epidemic event which started in the city of Wuhan, China in late 2019. By March 2020 the virus has spread globally and was declared as pandemic by the World Health Organization (World Health Organization, 2020). COVID-19 is an acute respiratory disease which may lead to pneumonia with symptoms such as fever, cough and dyspnea (Jiang et al., 2020) and has an approximate fatality rate of 2–3% (Rodriguez-Morales et al., 2020). As of March 19, 2020, there have

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**Table 1**
The most common background diseases evident in over 20% of the cases.

| Disease | % of patients |
|---|---|
| Hypertension | 73.8 |
| Diabetes | 33.9 |
| Ischemic heart diseases | 30.1 |
| Atrial fibrillation | 22.0 |
| Chronic renal failure | 20.2 |

been 209,839 confirmed cases and 8788 deaths reported globally. Early studies concluded that the risk factors associated with the development of the disease are older age (Wu et al., 2020), history of smoking (Liu et al., 2020), hypertension and heart disease (Chen et al., 2020). The Italian institute of health (Istituto Superiore di Sanità) reported background diseases of 481 patients in Italy who passed away due to COVID-19 infection. Table 1 shows the information about the most common background diseases which are evident in over 20% of the cases. Furthermore, recent studies suggest that the cause of death of many COVID-19 patients was related to cytokine storm syndrome (Guo et al., 2020; Mehta et al., 2020). This syndrome, also known as hypercytokinemia is an uncontrolled release of proinflammatory cytokines (Tisoncik et al., 2012) and it is a severe reaction of the immune system, leading to a chain of destructive processes in the body that can end in death.

Many studies have shown that the incidence of these diseases can also be caused by a long exposure to air pollution, especially nitrogen dioxide ($NO_2$), a toxic component. $NO_2$ enters the atmosphere as a result of anthropogenic activity (mostly fossil fuel combustion from vehicles and power plants) and natural processes (lightning and soil processes). Elevated exposure to $NO_2$ has been associated with hypertension (Saeha et al., 2020), heart and cardiovascular diseases (Gan et al., 2012; Mann Jennifer et al., 2002; Arden et al., 2004), increased rate of hospitalization (Mann Jennifer et al., 2002), chronic obstructive pulmonary disease (COPD) (De et al., 1993; Euler et al., 1988), significant deficits in growth of lung function in children (Avol et al., 2001; James Gauderman et al., 2000), poor lung function in adults or lung injury (Bowatte et al., 2017; Rubenfeld et al., 2005) and diabetes (Saeha et al., 2020). In addition to these, other studies have focused on the immune system's response to $NO_2$ exposure. Blomberg et al., 1999, found that exposure to $NO_2$ causes an inflammatory response in the airways and Devalia et al., 1993, showed that these exposures may induce the synthesis of proinflammatory cytokines from airway epithelial cells which consequently play an important role in the etiology (cause) of airway disease. Moreover, the epithelial cells in the lung may be uniquely susceptible to death when exposed to $NO_2$ (Persinger et al., 2002).

High $NO_2$ concentration is significantly associated with respiratory mortality (Beelen et al., 2008; Chen et al., 2007; Hoek et al., 2013) and is also responsible for generating some harmful secondary pollutants such as nitric acid ($HNO_3$) and ozone ($O_3$) (Khoder, 2002). As a result, the WHO has stated that the health risks may potentially occur due to the presence of $NO_2$ or its secondary products (World Health Organization, 2003). Accordingly, the WHO understands the health issues arising from $NO_2$ and suggests that the world population should be protected from exposure to this pollutant.

The objective of this work is to assess the contribution of a long-term exposure to $NO_2$ on coronavirus fatality. This is achieved by combining three databases: the tropospheric concentration of $NO_2$, the atmospheric condition as expressed by the vertical airflow, and the number of fatality cases. The data is processed at the administrative level for each country to obtain high spatial resolution.

## 2. Materials and methods

### 2.1. Fatality database

The data concerning the number of fatality cases was collected from each country on a regional/administrative level. The use of this method is intended to highlight the spatial variation of the epidemic which exists not only between different countries, but more importantly within each country. Moreover, if high mortality rates are observed in two remote regions in two different countries, we need to identify their common factor which may explain mortality. For that, data was collected from 66 administrative regions in Italy, Spain, France and Germany. Information about fatalities was taken from the Ministry of Health (Italy), Ministry of Health, Social Services and Equality (Spain), The National Agency of Public Health (France) and the Robert-Koch-Institute and the State Health Offices (Germany).

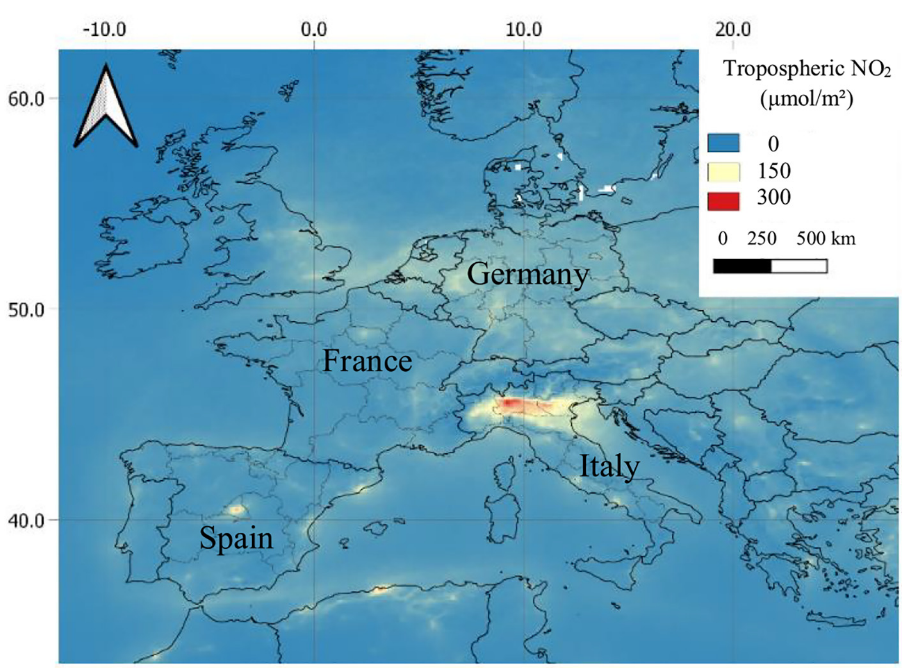


**Fig. 1.** The tropospheric $NO_2$ distribution.

### 2.2. The $NO_2$ spatial distribution

For the $NO_2$ concentration in the troposphere (from surface up to ~10 km), the Sentinel-5 Precursor space-borne satellite (spatial resolution of 5.5 km) was used which is operated and managed by the European Commission under the "Copernicus" program (Fig. 1). The satellite operates in a sun-synchronous orbit at 824 km and an orbital cycle of 16 days. The satellite carries a TROPOspheric Monitoring Instrument (TROPOMI) which provides a (near-)global coverage of air pollution caused by $NO_2$ and other pollutants such as $O_3$, $SO_2$, CO, $CH_4$, $CH_2O$ and aerosols (Veefkind et al., 2012).

For this study, long-term exposure was defined as a two-month period (January–February 2020) prior to the outbreak of COVID-19 in Europe. The spatial data was collected using the Google Earth Engine API (Gorelick et al., 2017). The global coverage of tropospheric $NO_2$ for this time period was extracted using 832 different images followed by calculating the mean concentration for each administrative region. Subsequently, only the maximum concentration value was used due to differences in the size of the regions.

### 2.3. The atmospheric condition

Due to the thickness of the troposphere, the value which represents the $NO_2$ concentration is not enough. There is also a need to understand the vertical airflow during the same period of the event. For that purpose, the vertical airflows at 850 mb (~1.5 km above sea level) was used as it defines the atmospheric capability to disperse the gas (Fig. 2). This data was provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA (http://www.esrl.noaa.gov/psd/). Downwards airflows are given by positive values of omega (in Pa/s), while upwards airflow by negative values of omega. In regions where positive omega is observed, the atmospheric will force the $NO_2$ to stay close to the surface which leads the population to be exposed to the risk factor. In contrast, in regions with negative omega, the atmospheric conditions will disperse the gas further away and to higher altitudes. In these regions, the population is less exposed to the air pollution and to its associated health risks.

## 3. Results

Mapping the tropospheric $NO_2$ over Europe reveals a major 'hotspot' of high concentration in the northern part of Italy. The 'hotspot' is

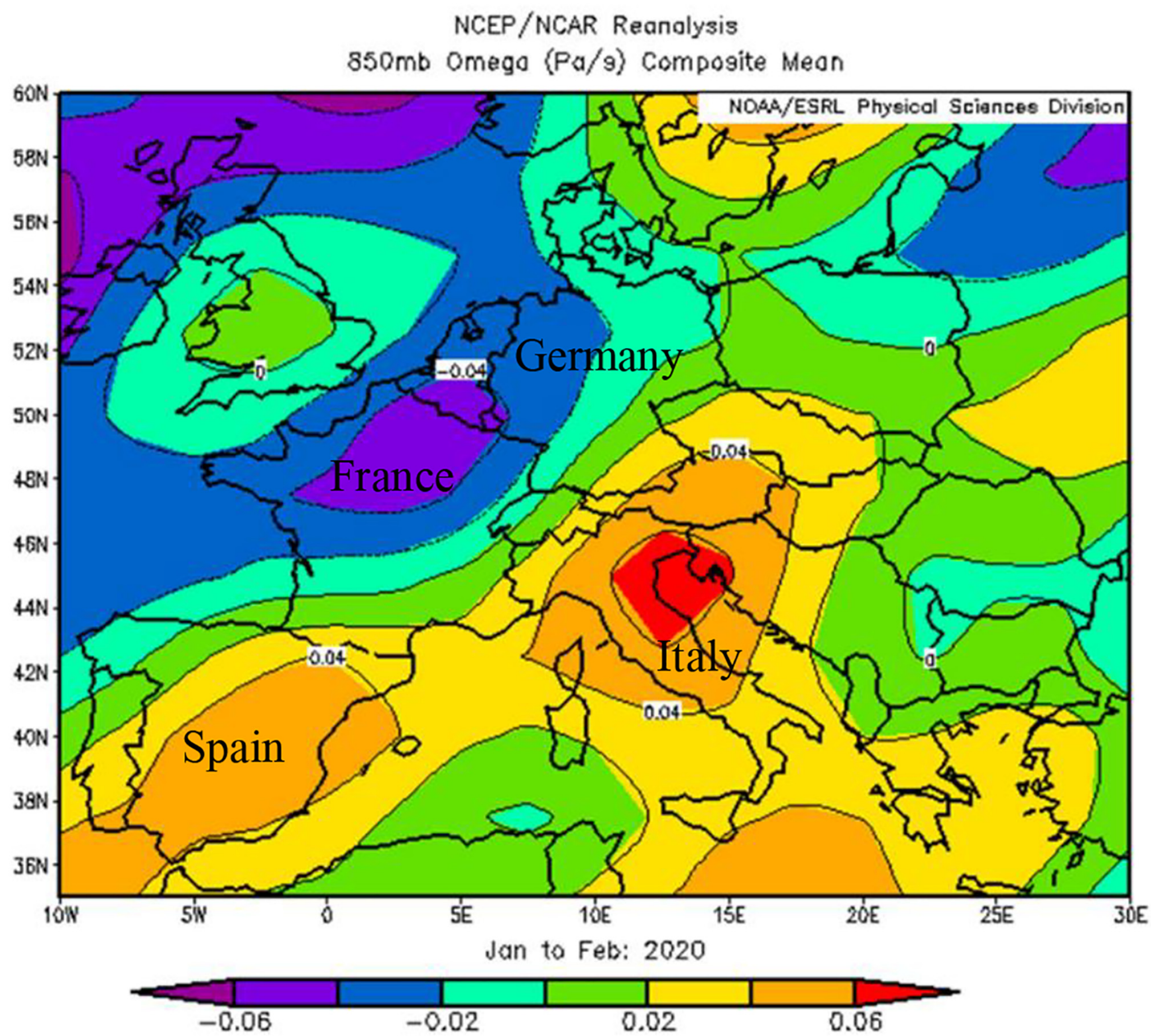


Fig. 2. The vertical airflow (omega) at 850 mb (~1500 m above sea level).

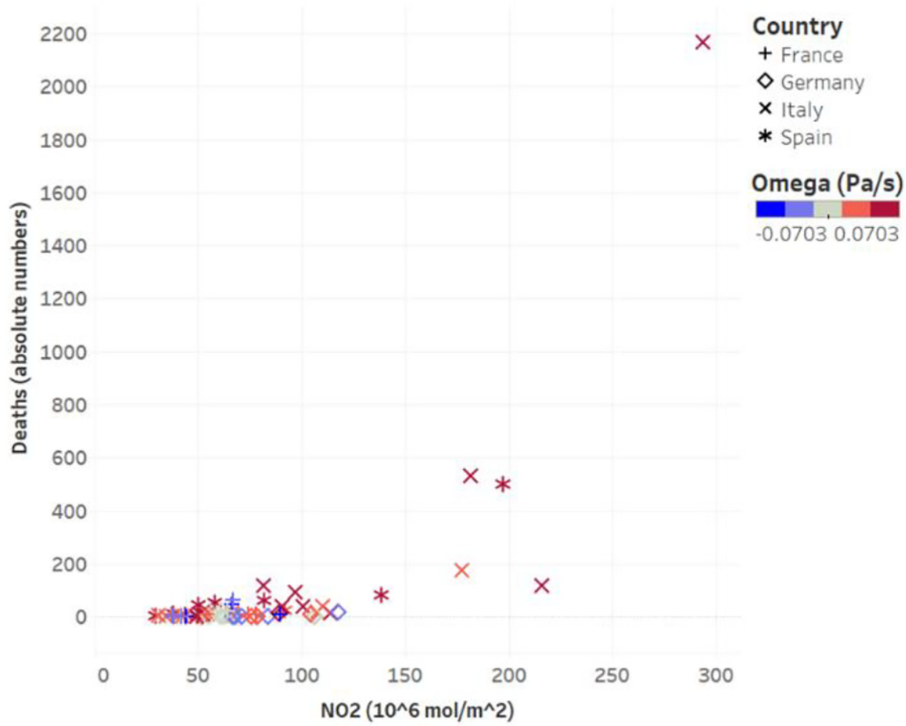


**Fig. 3.** NO2 vs. the absolute number of death cases.

observed in the Po valley which extends from the slopes of the western Alps to the coastal plains of the Adriatic Sea. Out of the top five regions where high fatality was observed, four of them were in northern Italy (Fig. 3): Lombardia, (2168 cases), Emilia-Romanga (531), Piemonte (175 cases) and Veneto (115 cases). The other region was in the administrative region 'Community of Madrid' (Comunidad de Madrid), Spain (498 cases) which, like the Po valley, is also surrounded by mountain ranges.

As shown in Fig. 4, 78% of all fatalities due to coronavirus in these selected countries occurred in those regions. The concentrations of $NO_2$ were high and ranged between 177.1 and 293.7 μmol/$m^2$, accompanied by downwards airflows (positive omega ranged between 0.04 and 0.07 Pa/s).

There were 4443 fatalities in these countries due to COVID-19 by March 19, 2020. 83% of all fatalities (3701 cases) occurred in regions where the maximum $NO_2$ concentration was above 100 μmol/$m^2$, 15.5% (691 cases) occurred in regions where the maximum $NO_2$ concentration was between 50 and 100 μmol/$m^2$, and only 1.5% of all fatalities (51 cases) occurred in regions where the maximum $NO_2$ concentration was below 50 μmol/$m^2$.

## 4. Discussion and conclusion

In this study, the concentrations of the tropospheric $NO_2$ which were extracted from the Sentinel-5P satellite were used in order to explain the spatial variation of fatality cases in 66 administrative regions in four European countries. The Sentinel-5P data shows two main $NO_2$ hotspots over Europe: Northern Italy and Madrid metropolitan area. According to these results, high $NO_2$ concentration accompanied by downwards airflows cause of $NO_2$ buildup close to the surface. This topographic structure combined with atmospheric conditions of inversion (positive omega) prevent the dispersion of air pollutants, which can cause a high incidence of respiratory problems and inflammation in the local population. This chronic exposure could be an important contributor to the high COVID-19 fatality rates observed in these regions. As earlier studies have shown that exposure to $NO_2$ causes inflammatory in the lungs, it is now necessary to examine whether the presence of an initial inflammatory condition is related to the response of the immune system to the coronavirus. Hence, poisoning our environment means

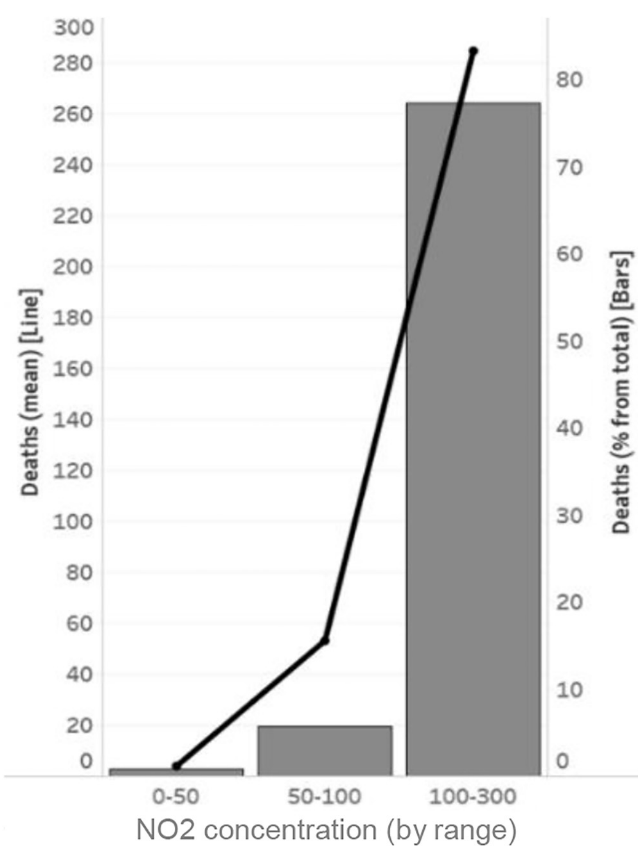


**Fig. 4.** The mean death cases and the percentage of deaths in each NO2 concentration range.

poisoning our own body and when it experiences a chronic respiratory stress, its ability to defend itself from infections is limited.

According to these results, more studies should be conducted which focus on additional factors such as age and presence of pre-existing and background diseases along with the impact of pre-exposure to $NO_2$ and hypercytokinemia in order to verify their impact on fatalities due to the COVID-19 pandemic.

## Declaration of competing interest

The author declares no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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