Assessment of health impact of the surface ozone on a population residing at Agadir city (Morocco) using the AirQ+ model

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Abstract. Several epidemiological and toxicological studies have shown that exposure to surface ozone increases deaths and illnesses. Deteriorating air quality could lead to health concerns in emerging countries such as Morocco. The aim of the present study was to investigate the long-term impact of ozone on the health of Agadir residents by using the AirQ+ model. The exposure reference values in 2016 were the daily and yearly average concentrations. Two monitoring stations provided the average ozone concentration per hour. The yearly total of maximum 8-hour ozone levels over 35 ppb was used to forecast probable long-term health impacts. As a health indicator, specific mortality for respiratory disorders was considered. According to the health impact assessment, the yearly cumulative incidence was estimated to 419.5 per 100,000 population. A reduction in ozone concentrations to less than 100 μg/m^3 might prevent 13 deaths per year (95% CI: 5–22), with an estimated attributable proportion of 0.73% (95% CI: 0.26–1.24). AirQ+ can be used as a public health tool to assess the health risks of air pollution, providing policymakers with a basis for implementing air quality management strategies to decrease air pollution's health effect. ***Keywords***: Ambient air pollution; health impact; log-linear model; AirQ; Ozone.

1 Introduction

Air pollution is declared as the biggest environmental factor increasing the risks of morbidity and mortality from congenital conditions and noncommunicable diseases such as cancers, diabetes mellitus, cardiovascular diseases, mental and neurological affections, as well as chronic lung diseases [1]. Also, according to the World Health Organization (WHO), there are 7 million premature deaths every year due to the combined effects of household and outdoor air pollution [2].

The triplet Oxygen (O_3) or ozone is an efficient greenhouse gas and a highly oxidative compound emitted in the lower atmosphere from gases and anthropogenic activities [3]. Tropospheric O_3 is a reactive molecule able to produce other photochemical oxidants and secondary air pollutants. Based on human and animal studies, high levels of O_3 exposure induce inflammation and lung epithelial cells damages [4]. Several recent studies have reported the significant impact of ozone emissions on human health [5,6,7,8]. Indeed, in their systematic review and meta-analysis, Huangfu and Atkinson indicated a linear association between the

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O_3 variable and all-cause mortality, and estimated a relative risk of 1.01 per 10 µg/m^3 (CI95%: 1.00-1.02) [9]. Likewise, according to Health Canada (2013) and the US EPA (2013), long-term ozone-respiratory and ozone-total mortality associations were deemed plausible or indicative of causality [10,11]. In its report on global air quality guidelines, the WHO noted a considerable increase in some pollutants such as particulate matter (PM), ozone, and nitrogen dioxide (NO_2). Moreover, population-weighted O_3 concentrations vary less than $PM_{2.5}$ levels (which refer to atmospheric particulate matter with a diameter less than 2.5 micrometres), and O_3 concentrations in South Asia exceed WHO air quality guidelines (WHO AQG). Despite the lack of studies, these concentrations can be as high in African megacities [12]. With regards to Agadir City, several sources of air pollution could be listed like dust from industrial and port units, trash incineration, traffic emissions, among others. So far, some physico-chemical studies on air pollutants and ozone concentrations were carried out in Agadir City [13,14]. The aim of the present study was then to assess and evaluate the health impact of ozone concentrations on a population living at Agadir city.

2 Materials and methods

This research was conducted in Agadir city located in southwest Morocco located on the Atlantic coast, it is situated at 30°25′12″ north latitude and 9°35′53″ west longitude and 31 meters above sea level (Figure 1). Agadir is the capital of the administrative Souss-Massa Region and the prefecture of Agadir Ida-Outanane. According to the last General Population and Habitat Census [15], Agadir urban population was estimated to 420,288 inhabitants. Annual rainfall totals 250 mm. The few days of rainfall occur between November and March. Temperatures are strongly influenced by the year-round trade wind front, and vary little between winter and summer. Average temperatures range from 14 to 16°C in January and 19 to 22°C in July.The WHO AirQ+ model was used to assess the health impact of O_3 [16]. This model was developed to evaluate the health impacts of different air pollution exposures, including $PM_{2.5}$, PM_{10}, NO_2, O_3, and black carbon. It has been utilized in many parts of the world and can assess both the long-term and short-term impacts of air pollution. It has been offered as a reliable method for calculating the health impacts of air pollution [17].

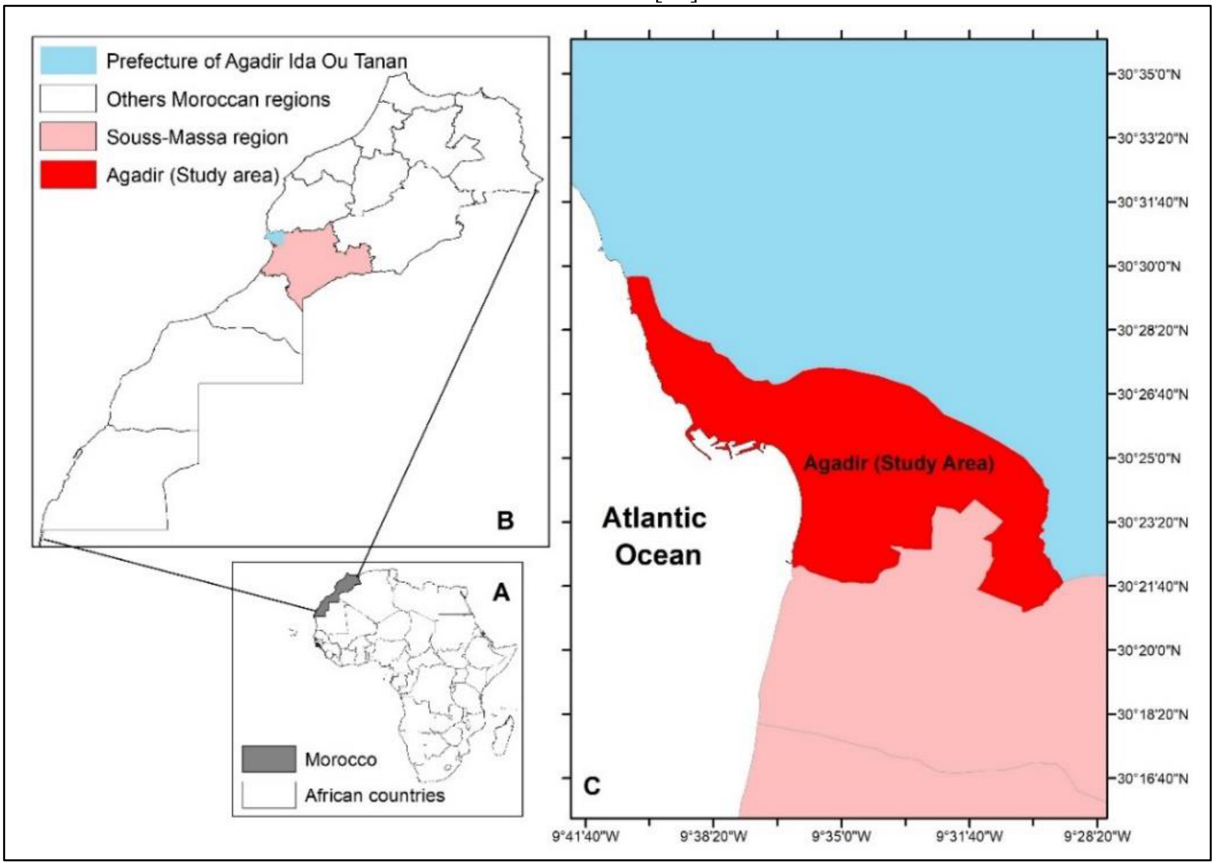

Figure 1. Location map of the study area: A. Morocco in Africa; B. Study area in Agadir Ida Ou Tanan Prefecture; C. Study area.

Ground-level ozone concentrations were measured in µg/m^3 or ppb, with 1 ppb equaling 2 µg/m^3. Monitoring station air quality measurements were typically given as hourly average ozone concentrations. As with other pollutants, data coverage of at least 75% is recommended.

To assess the health effects of ozone on the population, the SOMO35 indicator [18] defined as the sum of maximum 8-hour ozone levels over 35 ppb (70 µg/m^3) was utilized and calculated by applying the equation:

$$SOMO35_{unadjusted} = \sum_i max\{O, Ci - 35\,ppb\} \quad (1)$$

Where Ci is the maximum daily 8-hour average concentration of ozone (this parameter should not exceed 100 µg/m³ per day following the WHO AQG 2005), and the sum is annual, i.e., from day i = 1 to 365 per year. Other time periods are also possible, such as 180 days for an analysis of the summer months. SOMO35 has a dimension of (ppb × days) if 35 ppb is used, and (µg/m^3 × days) if 70 µg/m³ is used in the equation.

As SOMO35 is sensitive to missing values (i.e., days when daily maximum 8-hour average concentrations are not available), an adjustment must be made by taking the full time (e.g., annual) coverage according to this formula:

$$SOMO35 = SOMO35_{unadjusted} \times \frac{N_{total}}{N_{valid}} \quad (2)$$

Where N_{total} is the total number of days in the period of interest (365 for a year, 180 for the summer months), and N_{valid} is the number of days with valid values.
RR estimate was estimate using the following formula:

$$RR = e^{\beta \times \frac{SOMO35_{unadjusted}}{N_{valid}}} \quad (3)$$

Taking into consideration a central value of 1.014 per 10 µg/m3 to calculate the parameter β as:

$$\beta = \frac{\ln(1{,}014)}{10} = 0{,}0013903.$$

The log-linear model was used, considering the 5.27 µg/m^3 value as the average of ozone concentrations over 35 ppb (or 70 µg/m^3). Data from respiratory, infectious disease, medicine, otorhinolaryngology, pediatric, and intensive care unit departments were combined to estimate hospital deaths reported at Regional Hospital Center Souss-Massa located in Agadir city (RHCSM).

These analysis were carried out based on 2016 and 2017 monthly reports that were provided by the Regional Committee for Monitoring and Control of Air Quality of the Souss-Massa Region.

3 Results and discussion

Table 1 shows the average and maximum values of monthly O_3 concentration measurements in 2016 and 2017.
These data are taken from reports of measurement campaigns conducted by the mobile laboratory at three different locations. According to these reports, the values of the daily hourly averages measured are frequently below the Moroccan regulatory information threshold.

Take note of the inconsistency that affects these measurements at various locations. A reduction of the yearly ozone concentrations to less than 100 g/m^3 can avoid 13 of the 1763 estimated deaths due the respiratory diseases.

A network of permanent stations monitors ambient air quality in many countries. Such a network does not exist in Morocco, where just 29 stations are deployed in 15 cities.

As a result, the city of Agadir's restricted number of stations (three in number and primarily non-functional) makes it difficult to accurately describe the general population's exposure, which is the crucial link between ambient air pollution levels and the induced impacts on human health [19,20,21].

Modeling methods can be used as a substitute to actual measurements of air pollution. These tools enable us to understand the phenomena and extend current observations to locations devoid of instrumentation. OSPM [22], AERMOD [23], CALINE4 [24], ADMS-Urban [25], and SIRANE [26] are some of the most popular models. The models can handle air dynamics, or the movement of pollutants away from their origins, as well as chemical and photochemical reactions.

These modeling approaches may still be used to estimate emissions and their overall impact at the city scale, as well as to identify pollution hotspots.

Table 1. Air pollutant values measured in 3 stations in Agadir between 2016 and 2017 (Reports of the Regional Committee for Monitoring and Surveillance of Air Quality of the Souss-Massa Region, 2016 - 2017).

Station	Year	Month	O_3 (µg/m^3)	
			Daily mean value	Daily maximum value
Station 1	2016	April	47.56	59.21
		May	51.01	68.33
		June	44.20	67.09
		July	36.92	67.16
		August	25.32	52.69
		September	44.76	132.45
		October	44.76	68.76
		November	36.26	58.56
Station 2		May	65.37	130.00
		June	49.35	81.24
Station 3	2017	January	21.76	52.53
		February	41.02	67.21
		March	53.07	88.91
		April	78.76	94.84

According to Figure 2, a total of 71 and 49 deaths were reported by the hospital departments of cardiology-pneumology and infectious diseases, respectively in 2016. No mortality was reported by the department of otolaryngology during the same year. For each year from 2014 to 2018, the most observed admissions were to the department of cardiology-pneumology, followed by admissions to the department of otorhinolaryngology, and lastly admissions to the department of infectiology.

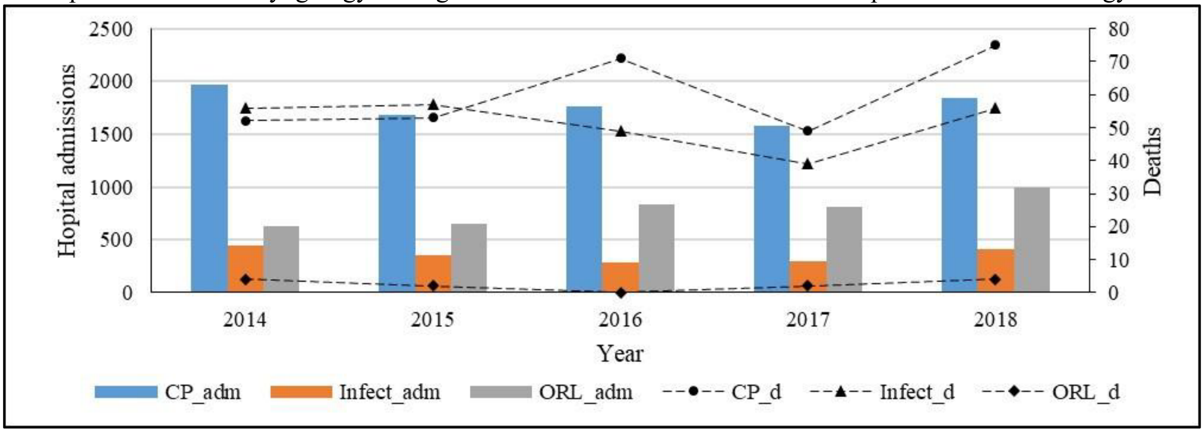

Figure 2. Admissions and deaths trends at the RHCSM from 2014 to 2018.
(CP: Cardiology and pneumology, Infect: Infectiology, ORL: Otorhinolaryngology, adm: admission, d: death)

Table 2 addresses the following question: how many cases of the total number of deaths from non-accidental causes reported at RHCSM in Agadir city among adults aged 30 and older are related to long-term exposure to ozone concentrations exceeding a daily average of 100 µg/m^3?
In 2016, 181 people died as a result of respiratory disorders (71 deaths in the cardio pneumology department, 12 deaths in the infectious diseases department, 10 deaths in the medicine department, 4 deaths in the otorhinolaryngology department, 16 deaths in the pediatrics department and 68 deaths in the intensive care unit). The population at risk in this circumstance totalizes 642,841 persons residing in Agadir Ida-Outanane Prefecture. Only cases reported at the cardiology-pneumology service level were used to obtain an estimate of the impact and the burden of respiratory disorders. The unadjusted SOMO35 was expected to be 948 µg/m^3.

Table 2. Results in AirQ+ of the long-term health impact assessment of ozone on respiratory mortality during 2016.

Health endpoint	Age	At-risk population	Hospital deaths	Annual incidence per 100,000 inhabitants	RR (CI 95%) [a]	Estimated attributable proportion (%)	Estimated number of attributable cases	Estimated number of attributable cases per 100,000 population at risk
Respiratory mortality [b]	All ages	420,288 [c]	1763 [d]	419.47	1.01 (1.00 – 1.01) [e]	0.73 (0.26 – 1.24)	13 (5 – 22)	3.06 (1.10 – 5.21)

[a]: Relative risk with its 95%confidence interval.
[b]: Log-linear computation method, RR (X) = $e^{\beta (x - x_0)}$; β = 0.0013902905168991435 (0.0004987541511038968 – 0.0023716526617316063), average concentrations for x > 70 μg/m³ = 5.2667 μg/m³.
[c]: Population using RHCSM departments: only the population of the Agadir Municipality was considered here (data from the General Census of Population and Habitat, 2014).
[d]: Only deaths from the cardiology and pneumology departments were considered.
[e]: Relative risk with its 95% confidence interval for a threshold value of 100 μg/m³ (WHO AQG 2005).

4 Conclusion

The AirQ+ data revealed the yearly number of health events that might be avoided if the air quality were improved. Based on a public health approach, this assessment provides diagnostic features to decision-makers to help them define local air quality improvement targets. Due to some limitations of this software, it is suggested to consider with caution the generated findings of the present study unless submitted to expert evaluation. Nonetheless, air quality must be addressed while developing public policy. Locally, vehicle traffic is a major source of degradation in urban air quality. Consequently, sensor deployment for air pollution monitoring and surveillance along heavy traffic roads could be suggested. The development of an integrated public-private system recording not only deaths but also all information about patients admitted to medical consultation at both the primary healthcare center and hospital facilities is to be further recommended.

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