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POTENTIAL ENVIRONMENTAL IMPACT ON HEALTH DUE TO ATMOSPHERIC POLLUTANTS USING AIRQ+ SOFTWARE IN LA PAZ AND EL ALTO, BOLIVIA

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Air pollution generates around seven million deaths annually throughout the world according to data from the World Health Organization. The research evaluates the impact of suspended particulate matter with a diameter of less than 10 microns (PM10) in La Paz and El Alto, Bolivia, and its relationship with non-viral respiratory diseases, through on-site information, historical epidemiological data between 2009 and 2019. and the free software AirQ+. It was determined that 35.45% of cases of non-viral respiratory diseases could be attributed to PM10 in La Paz; For El Alto, data from 2016 suggest a relationship with the incidence of chronic bronchitis in adults at 41.53%, a relationship with postneonatal infant mortality at 17.32%, and a prevalence of bronchitis in children of 31.15%. For La Paz, a simulated scenario where the concentration remains below the permissible limits, suggests a reduction in the prevalence of non-viral diseases attributable to PM10 of 2.75% in post-neonatal infant mortality, 4.83% in causes of bronchitis in children under five years of age and 16.2% in chronic bronchitis in adults; For El Alto, a similar impact is expected considering that the permissible limit values were exceeded by 30%.

Keywords: suspended particulate matter with a diameter of less than 10 microns (PM10); respiratory diseases; mathematical modeling

POTENCIAL IMPACTO AMBIENTAL EN LA SALUD POR CONTAMINANTES ATMOSFÉRICOS MEDIANTE EL SOFTWARE AIRQ+ EN LA PAZ Y EL ALTO, BOLIVIA

La contaminación atmosférica genera alrededor de siete millones de muertes anuales en todo el mundo según datos de la Organización Mundial de la Salud. La investigación evalúa el impacto del material particulado suspendido con diámetro menor a 10 micras (PM10) en La Paz y El Alto, Bolivia, y su relación con enfermedades respiratorias no virales, mediante información en sitio, datos históricos epidemiológicos entre los años 2009 y 2019 y el software libre AirQ+. Se determinó que el 35,45% de casos de enfermedades respiratorias no virales podrían atribuirse al PM10 en La Paz; para El Alto, los datos del año 2016 sugieren relación con la incidencia de bronquitis crónica en adultos en 41,53%, relación con mortalidad infantil postneonatal en 17,32% y prevalencia de bronquitis en niños del 31,15%. Para La Paz, un escenario simulado donde la concentración se mantiene por debajo de los límites permisibles, sugiere reducción en la prevalencia de enfermedades no virales atribuibles a PM10 de 2,75% en mortalidad infantil post neonatal, 4,83% en causas de bronquitis en niños menores a cinco años y 16,2% en bronquitis crónica en adultos; para El Alto, se espera similar impacto considerando que los valores límites permisibles fueron superados en un 30%.

Palabras clave: material particulado suspendido con diámetro menor a 10 micras (PM10); enfermedades respiratorias; modelación matemática

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1. Introduction

In Latin America and the Caribbean (LAC), at least 100 million people are exposed to air pollution levels above those recommended by the World Health Organization (WHO) (Cifuentes et al, 2005). Vulnerable groups to the harmful effects of poor air quality include children, the elderly, people with previous health problems, and people from low socioeconomic strata. Both the WHO and the United Nations Environment Program (UNEP) have highlighted environmental air pollution as one of the strategic focal areas to address due to their influence in mortality and morbidity worldwide (Clean Air Institute, 2021). Poor air quality also has a negative impact on social and economic development, affecting the competitiveness of countries. Health diseases resulting from air pollution costs billions of dollars annually in medical costs and lost productivity. Health impacts in LAC countries such as Bolivia, Guatemala, Ecuador, Peru, and El Salvador, are estimated as up to 2% of the Gross Domestic Product (GDP) (Cifuentes et al, 2005).

Different agents determine air quality. Particles in general are produced by many natural and anthropogenic processes (Suarez, 2012). Due to their impact on health, they are considered pollutants of high concern. The diameter of the particles present in air varies from 1000 of a micron to 500 microns. From the point of view of human health, particles whose size does not exceed 10 microns (PM10) are the most harmful (Portal Ambiental Andalucía, 2004). Due to the size in which these particles can occur in the atmosphere, they have the potential to penetrate deep into the lungs, which induces a reaction in the defense cells in the lungs and these effects can be perceived in the short or long term in health, causing lung conditions and heart diseases (PAHO, 2021).

Since year 2000 the Air Quality Monitoring Network in Bolivia (Red MoniCA) registers valuable data to support decision makers (Luján, 2008); nevertheless, there are few studies that correlate the impact of particle pollution to health. To address that issue and in compliance with the SDG 3 Health and well-being, this research applies the AIRQ+ software to provide an approximation to the possible impacts that particles smaller than 10 μm (PM_{10}) can generate on the health of the population.

2. Methodology

2.1 Study area

We are focused on the urban areas of both the Municipalities of La Paz and El Alto, where there are intense activities regarding public and private transportation, which are the main sources of particle pollution. La Paz is located at 3600 meters above sea level (GAMLP, 2021) and the city of El Alto at 4150 meters above sea level; the high-altitude conditions promote the dispersion of particles due to the dynamics of winds that are generated in the region.

Figure 1: Monitoring stations of PM_{10}, La Paz and El Alto cities

Source: *Adaptation of Google Earth, 2022*

2.2 Data collection

It is used the database provided by the Ministry of Health in Bolivia, in reference to non-viral respiratory diseases incidence both in the Municipality of La Paz and El Alto. Analysis was limited to chronic bronchitis in adults, post-neonatal infant mortality, and bronchitis in children. Regarding the concentration levels of PM_{10}, we worked with data generated by the Red MoniCA of both cities, considering 24-hour monitoring through an active methodology with employment of a Harvard MiniVol Impactor, which allows the determination of the concentration through gravimetry (Table 1). The period analyzed is from 2014 to 2019. The monitoring points considered are presented in Table 2. Population growth rates was established from the National Institute of Statistics (INE) database.

Table 1: Record of number of non-viral diseases registered in La Paz and El Alto

City		Year					
		2014	2015	2016	2017	2018	2019
La Paz	Chronic bronchitis in adults	39710	24618	25251	29835	29356	29091
	Post neonatal mortality	7515	7017	6910	1104	6945	8325
	Bronchitis in children	2838	2182	1923	1567	1789	1450
El Alto	Chronic bronchitis in adults	158	282	4560	1721	2687	1781
	Post neonatal mortality	134	148	334	1208	1053	1178
	Bronchitis in children	80	268	263	1335	2024	1472

Source: Based on data from the Ministry of Health in Bolivia, 2023.

Table 2: Monitoring points

City	Monitoring points		
La Paz	Villa Fátima (VF)	Cotahuma (CH)	Tránsito (TR)
El Alto	Ciudad Satélite (CS)	Alcaldía Quemada (AQ)	Avenida Bolivia (AB)

2.3 AirQ+ Software

AirQ+ is a software developed by the Health Impact Assessment of Air Pollution (HIAAP) program run by the Bilthoven Division of the WHO (WHO, 2008). It is free for Windows and Linux operating systems. The software estimate health impacts based on the calculation of the percentage attributable (PA) for a given short- and long-term health effect associated with exposure to a specific pollutant from the exposure data of the population within a defined urban area (WHO, 2020). For the determination of the attributable percentage of the impact on health by PM_{10}, the AirQ+ software uses the equation proposed by Krzyzanowski (WHO, 2001):

$$AP = \frac{\sum\{(\mathrm{RRRR(CC)}-1)\mathrm{XP(C)}\}}{\sum[\mathrm{RR(C)}\times\mathrm{P(C)}]} \quad (1)$$

Where: *AP* is the attributable percentage of the population that could be affected by pollutants, RR is the relative risk of a certain effect on health and (C) is the population in contact with a pollutant.

The rate attributable to contact is determined by Eq. (2), if the frequency of the health effect in the studied population is identified.

$$IE = I \times AP \quad (2)$$

Where: IE is the health effect rate attributable to contact with the contaminant, I is the reference frequency of the health effect in the population respectively. Using equation (3) the number of people attributable to exposure is calculated

$$NE = IE \times N \quad (3)$$

Where: NE is the number of people that can be attributable to the exposure, N is the total number of people who suffered from non-viral respiratory diseases in the given study location.

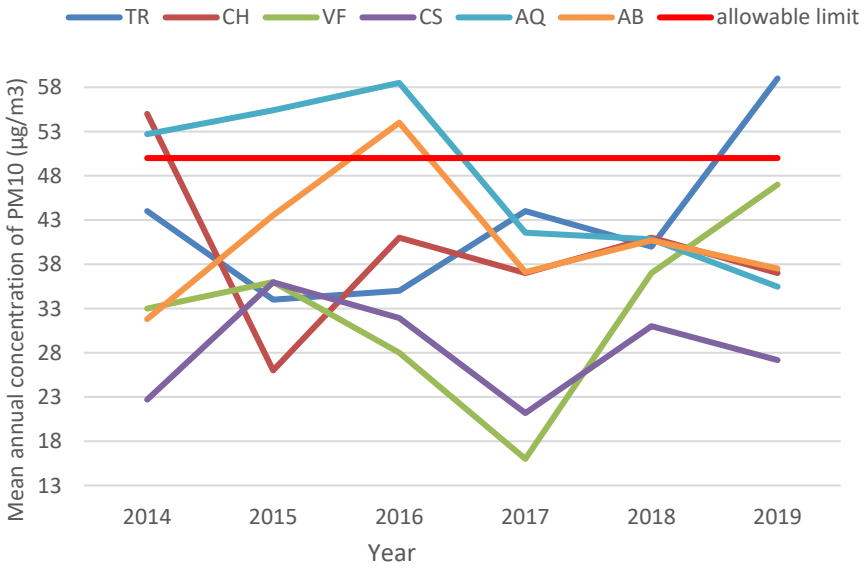
As established by Lujan (2008), the model cannot establish a direct causal relationship and cannot analyze synergistic effects that can be produced by the presence of various pollutants in the atmosphere.

3. Results

3.1 Average concentration of PM_{10}

For both cities, the average annual concentration at each monitoring point was considered, comparing it with the permissible limit of 50 ($\mu g/m^3$), in 24-hour monitoring periods, established in the Regulation on Atmospheric Pollution (RCMA) of Law 1333 of Bolivia. The permissible limit is exceeded at six monitoring points in different efforts: CH and AQ (2014); AQ (2015); AQ and AB (2016) and TR (2019), thus excluding from the analysis the periods that present a concentration below this. The PA value of the affected population is determined with the range of variation considering a confidence interval (CI) of 95% in each case.

Figure 1: Average PM_{10} annual concentration



Source: Own elaboration, based on records of the MoniCA Network of La Paz and El Alto, 2023.

In year 2014 (Figure 2), a PA for chronic bronchitis in adults at the CH and AQ monitoring points of 41% and 37%, respectively, are attributed to the effects of PM10 pollution; for post neonatal mortality of 17 and 15%; and finally, 30 and 27% for infantile bronchitis. In year

2015 (Figure 3) the permissible limit at the AQ monitoring point is exceeded, obtaining the highest PA for chronic bronchitis in adults of 39%, followed by 28% for childhood bronchitis, 17% attributable to other causes and 16% to post neonatal mortality. A higher incidence regarding other causes occurs during the year 2016 (Figure 4) in the AB station with a PA of 37%; as for chronic bronchitis in adults, the PA at the AQ monitoring point was 42% of the registered non-viral disease cases. Finally, in year 2019 (Figure 5), it is only identified that the permissible limit is exceeded by the average annual concentration reported at the TR monitoring point. The PA in this case are 42% for the generation of chronic bronchitis in adults, 17% for post-neonatal mortality, 25% for chronic bronchitis and 16% relative to other causes.

Figure 2: Percent Attributable (PA) – 2014

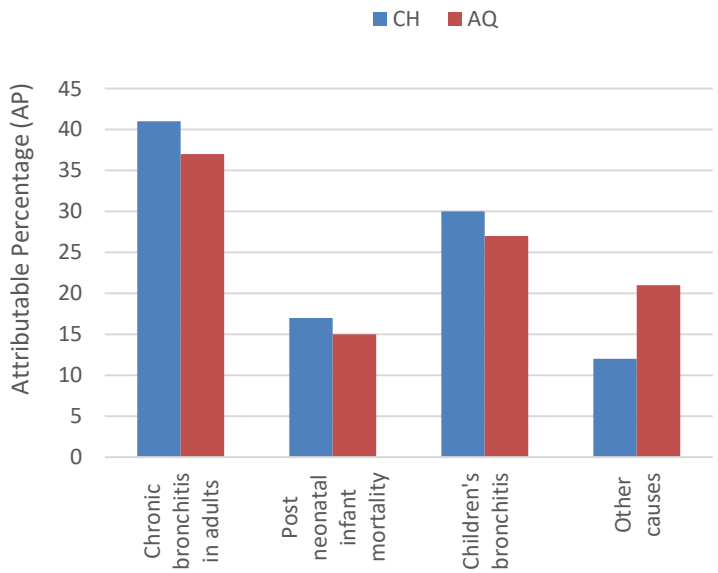


Figure 3: Percent Attributable (PA) – 2015

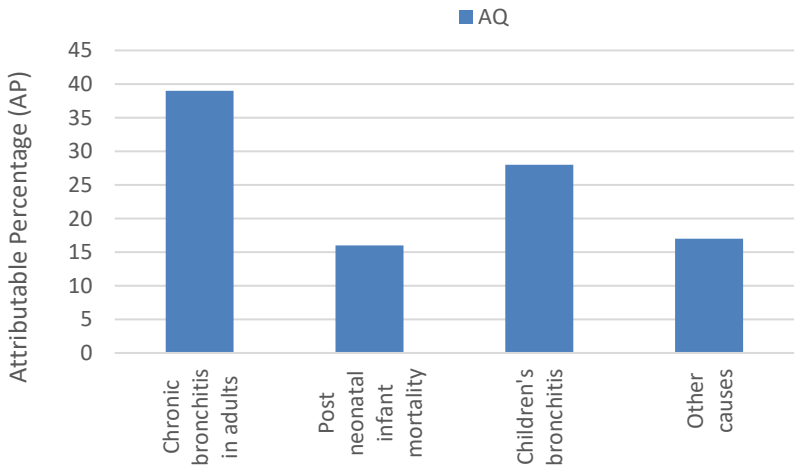


Figure 4: Percent Attributable (PA) – 2016

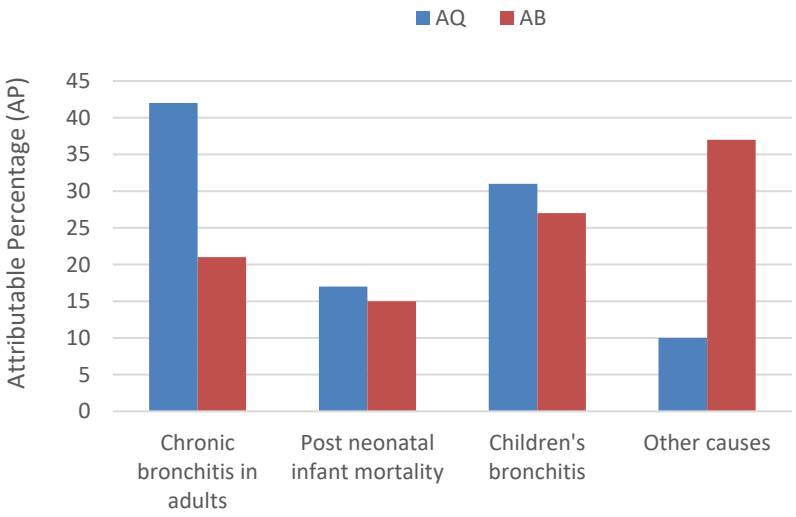
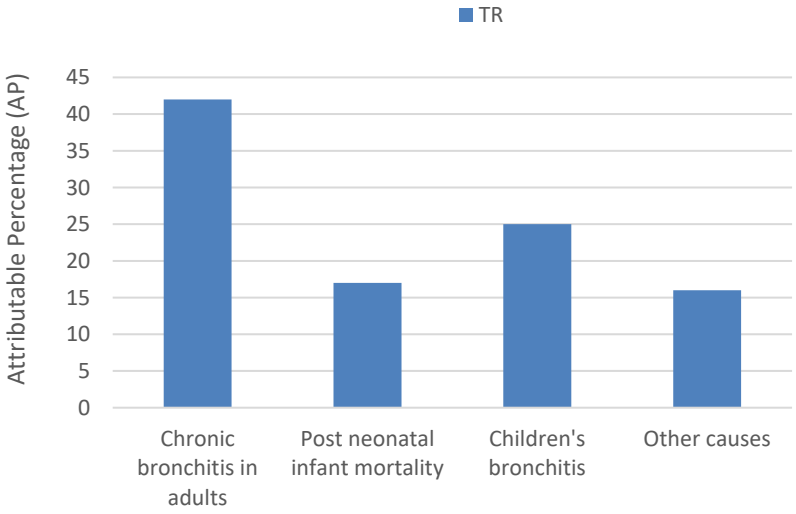


Figure 5: Percent Attributable (PA) – 2019



4. Conclusions

In accordance with the results obtained, a significant impact on health can be attributed to PM_{10}, especially with regard to non-viral respiratory diseases such as chronic bronchitis in adults, post neonatal infant mortality and childhood bronchitis, among the most significant. This situation is corroborated by the provisions of the State Comptroller General's Office (2019), where it was stated that the influence on the health of the population exposed to this pollutant is imminent.

In the context of the cities of La Paz and El Alto, according to the AirQ+ analysis and the average annual concentrations of PM10 registered in the six active monitoring stations of the

MoniCA Network, there a significant impact in the health of the population. The general Attributable Percentages to the impact of the PM_{10} concentration to which people are exposed at each of the monitoring points is 35% and 30% in each of the cities, respectively.

The monitoring points in which there is a higher incidence attributable to the generation of non-viral respiratory diseases are: TR in the city of La Paz and AQ in the city of El Alto. Both monitoring points are characterized by an important influence of vehicular traffic in the sector, which is why they are significant regarding the evaluation of air quality in both cities.

Regarding the years selected for the analysis, it is evident that there is a higher incidence of diseases in the AQ point of the city of El Alto, in year 2016 with 42% for chronic bronchitis in adults, 17% for post neonatal mortality and 31% for childhood bronchitis. In relation to La Paz, the highest attributable percentage was determined in the CH point around chronic bronchitis in adults (41%).

Regarding some scenarios in both cities, a reduction in the concentration of PM_{10} could be achieved considering that there is compliance with the permissible limit values established by the RMCA, resulting in a reduction in the attributable percentage for chronic bronchitis in adults by up to 16.2% in La Paz and 23.2% in El Alto, and for post neonatal infant mortality in 2.75% and 2.82%; and for infantile bronchitis of 4.83% and 1.23% respectively. Future work should focus, among other on the establishment of future scenarios based on the updated guidelines on air quality, established in 2021 by the WHO, in order to produce comparable results.

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Comunicación alineada con los Objetivos de Desarrollo Sostenible