Air pollution, well-being, and quality of life in Latin America: a systematic review

Contaminación atmosférica, bienestar y calidad de vida en América Latina: una revisión sistemática

Boris ÁLVAREZ
boris.alvarez@ufrontera.cl
Doctorate in Social Sciences
University of La Frontera
(Chile)

Àlex BOSO
alex.boso@ciemat.es
alex.boso@ufrontera.cl
Department of Environment
CIEMAT
(Spain)
Social Sciences Department
University of La Frontera
(Chile)

Arturo VALLEJOS-ROMERO
arturo.vallejos@ufrontera.cl
Social Sciences Department
University of La Frontera
(Chile)

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(Chile)

Arturo VALLEJOS-ROMERO
arturo.vallejos@ufrontera.cl
Social Sciences Department
University of La Frontera
(Chile)

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Abstract

The aim of this review was to describe the effects of air pollution on well-being and quality of life in Latin American countries, following the systematic methods of the PRISMA-P guidelines. A systematic search of empirical studies published in Web of Science (WoS), Scopus, SciELO and PubMed databases was performed. Thus 17 relevant studies published between 1986 and 2021 were identified: 16 with quantitative designs and 1 a qualitative design. The selected studies were grouped into three thematic approaches: mental health (41 %), negative emotions (35 %) and subjective well-being (24 %). The results indicate that air pollution influences various components of well-being, such as satisfaction with life, subjective well-being, perception of quality of life, symptoms of depression or anxiety, negative emotions such as anguish, annoyance, and frustration, among others. However, there were also multiple empirical gaps to be filled.

Keywords: air pollution, subjective well-being, psychological well-being, emotional distress, Latin America.

Resumen

El objetivo de este artículo fue describir los efectos de la contaminación atmosférica sobre el bienestar y la calidad de vida en los países latinoamericanos, siguiendo los métodos sistemáticos de las guías PRISMA-P. A tal fin, se realizó una búsqueda sistemática de estudios empíricos publicados en las bases de datos de WoS, Scopus, SciELO y PubMed. Así, se identificaron 17 estudios relevantes publicados entre 1986 y 2021: 16 con diseños cuantitativos y 1 con diseño cualitativo. Los estudios seleccionados se agruparon en tres enfoques temáticos: salud mental (41 %), emociones negativas (35 %) y bienestar subjetivo (24 %). Los resultados indican que la contaminación acústica influye en varios componentes del bienestar, como la satisfacción con la vida, el bienestar subjetivo, la percepción de la calidad de vida, los síntomas de depresión o ansiedad, las emociones negativas como la angustia, la molestia y la frustración, entre otras. Sin embargo, también había múltiples vacíos empíricos que llenar.

Palabras clave: contaminación atmosférica, bienestar subjetivo, bienestar psicológico, malestar emocional, América Latina.

1 Introduction

Air pollution is one of the most critical global environmental problems that authorities must address. A study by Vohra *et al.* (2021) calculates that more than ten million people die every year due to air pollution from fossil fuels. Exposure to high pollution levels has consistently been associated with multiple harmful health effects at both the respiratory and cardiovascular levels (Newell *et al.* 2017, Salinas *et al.* 2018). Harmful effects of air pollution have also been reported for prenatal development, as well as the development of physical or cognitive diseases in children and adolescents (Lertxundi *et al.* 2019).

The detrimental consequences of air pollution can extend beyond physical health, affecting other dimensions of people's mental health and quality of life; for instance, some studies have identified a correlation between air pollution and several psychological disorders, including anxiety, depression, bipolar disorder, schizophrenia, Alzheimer's, autism, and suicidal ideation. Additionally, it has been associated with a decline in optimism, satisfaction with life, happiness, and well-being in general (Casas *et al.* 2017, Shin *et al.* 2018, Khan *et al.* 2019). Additionally, air pollution has also been considered a risk factor associated with other social problems such as substance abuse (Lu 2020), school absenteeism (Liu & Salvo 2018) or the reduction of work productivity (Aragón *et al.* 2017). This indicates that air pollution can possibly modify the way in which people live and assess their overall quality of life (Li *et al.* 2019). Understanding the effects of air pollution on people's well-being and quality of life is a fundamental task for both academics and public policy makers.

1.1. Well-being and quality of life

The theoretical scope of quality of life is broad and diverse, including physical, psychological, social, cultural, economic, political, and environmental components (Kumar 2019). The World Health Organization (WHO) defines the *quality of life* as the «individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns» (WHOQOL Group 1993, p. 1). In the 1930s, formal studies on this concept focused on objective data of living conditions such as socioeconomic level, education level or type of housing. However, at the end of 1960s, the debate redirected to subjective components from psychology, a discipline traditionally interested in the study of emotions, happiness, subjective well-being, and satisfaction with life (Theofilou 2013). This brought about the emergence of two great traditions of well-being that are still present today: the hedonic and the eudaimonic.

The *hedonic* tradition posits that a person's central motivation is the search for happiness, pleasure, avoidance of pain, self-preservation, and self-improvement. This approach concentrates on people's subjective judgment about their well-being or life satisfaction, being a more emotional line (Huta 2016). The hedonic tradition has been developed theoretically through subjective well-being, which is defined as a cognitive and affective valuation that the person makes of their life in general or specific aspects of it (*e.g.,* family, work, health…) (Flores *et al.* 2018). These assessments can be positive or negative and include judgments and feelings with respect to satisfaction with life, interests and commitments, affective reactions like enjoyment and purpose and other important domains (Diener & Ryan 2009).

On the other hand, the *eudaimonic* tradition, which reflects the ability to lead a full life, with purpose and meaning. Predominantly developed from psychological well-being, this tradition is interested in aspects such as self-realization, personal and social performance, and in positive social relationships (Ryan & Deci 2001, Ryff 2018). This construct offers a more theorized understanding of well-being, using psychological concepts taken from Erikson's stage theory, Maslow's concept of self-actualization, and Roger's description of a functional person, among others (Ryff & Keyes 1995). From this, Ryff (1989) proposes a multidimensional model of well-being that reclaims various indicators of positive psychological functioning. This model includes six dimensions: *i)* self-acceptance, understood as a positive valuation of one's past life; *ii)* personal growth, a sense of continuous development as a person; *iii)* purpose in life, as the belief that one's own life has purpose and meaning; *iv)* positive relations with others, having quality relationships with other people; *v)* environmental mastery, ability to effectively manage one's own life and the surrounding world, and *vi)* autonomy, as a sense of independence and self-determination.

1.2. Emotional distress

On the opposite side is the concept of «emotional distress», which emerges from observations in biomedicine on the presence of various emotional manifestations of discomfort or suffering reported by patients, but which did not comply with all the standards to be qualified as a clinical-pathological presentation. In this sense, emotional distress is understood as a subjective sensation of reduced well-being or as a disagreeable emotional experience that affects a person's cognitive, behavioral, social, emotional, and spiritual functioning (Hernández *et al.* 2012).

Complementarily, authors such as Espíndola *et al.* (2006) and Viertiö *et al.* (2021) maintain that emotional distress refers to non-specific symptoms of depression, anxiety, and stress, which appear when a person perceives that a stressful event exceeds their

resources to confront it. Air pollution is considered a psychobiological stressor that produces physical, emotional, and behavioral changes, affecting the well-being of those exposed to this situation (Lundberg 1996). The manifestations of psychological distress are essentially observed at the affective level, with depressive emotions such as sadness, irritability and loss of interest, and anxious emotions such as hopelessness, discontent, fear, and others.

1.3. Air pollution in Latin America

Numerous studies link air pollution and aspects relative to quality of life like mental health and well-being in heavily industrialized countries like China, the United States, England, Italy, Spain, Germany, and the Netherlands. Nevertheless, previous systematic reviews on this relation rarely report studies in Latin American contexts or in low- or middle-income countries (Li *et al.* 2018, Braithwaite *et al.* 2019). This is relevant, since how the issue of air pollution is configured and its potential effects on human life vary considerably among countries with differing social, economic, demographic and climate situations.

Although air pollution is a global problem, the countries in the Global South[1] tend to be more affected by its consequences. Smith (2002) mentions that most of the exposure to harmful levels of indoor pollution occurs in poor countries and not in high-income countries, where the most significant efforts in research and monitoring have been focused. Thus, a large part of the impact of air pollution on global health occurs in socially vulnerable populations residing in low and medium-income countries (Troncoso & Soares da Silva 2017). The combination of rapid population growth, escalating industrialization, and urbanization in countries across the Global South has resulted in densely populated urban centers with poor air quality (Burroughs & Rollins 2017). Nowadays, multiple cities in several Latin American countries such as Peru, Chile, Colombia, Brazil, and Mexico have exceeded the annual levels of air pollution recommended by the WHO (> 10 μg/m^3) in the last five years (IQAir 2023). It is estimated that more than ninety million people use solid fuels for heating or cooking in Latin America and the Caribbean, especially in rural areas (Bruce *et al.* 2000, Troncoso & Soares da Silva 2017). By contrast, in high-income countries, solid fuel use is low, and their leading causes of air pollution are usually the high number of motor vehicles, the presence of industries in urban sectors, and the generation of energy based on coal or oil (Liao *et al.* 2015a, Sarwar *et al.* 2019).

In addition, unlike what happens in the Global North,[2] where in recent decades effective interventions have been implemented to fight the high exposure to particulate matter, Latin American public policy has been less effective (Querol *et al.* 2006, Bennett *et al.* 2019). Riojas-Rodriguez *et al.* (2016) indicate that the rules and

1 Term that broadly refers to countries outside of Europe or North America that are mostly low-income and have been politically or culturally marginalized. This concept belongs to the family of terms such as «Third World» or «Periphery», but it introduces a greater emphasis on geopolitical power relations (Dados & Connell 2012).

2 It refers to high-income, technologically advanced, politically stable-countries with a tendency to demographic aging (Odeh 2010). The Global North includes mainly the European continent along with many other developed countries such as the United States, Canada, United Kingdom, Russia, Turkey, Israel, South-Korea, Japan, Hong Kong, Singapore, Taiwan, Australia, and New Zealand.

regulations in Latin American countries on pollution control are heterogeneous and, in a certain sense, inconsistent: the great majority do not follow the WHO recommendations on tolerable pollution levels, and many highly polluted regions do not even have adequate monitoring systems. Additionally, there are noticeable differences in house construction regulations. The standards for thermal insulation, energy efficiency, and overall quality of dwellings are generally lower in Latin American countries compared to those in European countries or the United States (Young 2014). These conditions cause greater energy demand and, consequently, greater cost in fuel, which is often of low quality (Reyes *et al.* 2019, Boso *et al.* 2022).

The aim of this review is to describe the effect of air pollution on the subjective or psychological well-being and emotional distress in the context of the Latin American countries through a systematic method of search and report.

2 Materials and methods

This systematic review was performed following the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses protocols (PRISMA-P) to report and synthesize outcomes (Page *et al.* 2021).

2.1. Inclusion and exclusion criteria

Included studies had to *a)* be empirical scientific articles; *b)* be written in Spanish, English or Portuguese; *c)* address the effect of air pollution on quality of life, well-being (subjective or psychological), emotional distress or stress and other concepts derived from these traditions, and *d)* be conducted in Latin American countries.

On the other hand, we excluded: *a)* non-peer-reviewed scientific articles; *b)* books, book chapters, theses, reports, conference proceedings, reviews, or protocols; *c)* studies only with participants under eighteen years of age, and *d)* studies with non-human populations. Since our goal was to identify everything that has been written on this subject, we did not establish any parameters or limits regarding the publication date of the articles.

2.2. Search methodology

To conduct this search, four scientific databases were consulted: WoS, Scopus, SciELO and PubMed. In each database, the search was conducted by incorporating free terms, MeSH terms and Boolean terms. The search terms had to be present in the title, abstract or the author's keywords.

Four large groups of words in English were used: first, referring to air pollution, words such as «air pollution», «air quality», «particulate matter», and other synonyms were included. Second, for the terms relative to «quality of life», concepts such as «subjective well-being», «psychological well-being», «emotional distress», «life satisfaction», «happiness», «mental stress», «anxiety», or negative emotions such as «annoyance», «sadness», «fear» and others were included. The third group of words referred to the Latin American territory using terms like «Latin America» or «South America», «Central America», and «Caribbean», in addition to the names of the 38 countries that comprise Latin America and the Caribbean. Finally, a fourth group was added with exclusion terms such as «rat», «mice», «fish», «nonhuman», «animal», «child», «infant», «newborn», «teenager» or «toddler». The first three groups of words were combined with the Boolean term «AND» while the fourth exclusion group was combined with the terms «AND NOT». This review was performed on December 31, 2021.

2.3. Selection process

The review and article selection process were performed by two researchers to reduce possible eligibility biases. First, the studies selected from the four databases were downloaded and entered the EndNote X9 reference manager. Then, duplicate articles were identified and removed using the «find duplicates» function. Second, the two researchers independently reviewed the title and abstract of each article to select those most suitable for the systematic review based on the previously established inclusion and exclusion criteria. Selection discrepancies were discussed between the two investigators to reach a consensus about their inclusion or exclusion on the final article list. Next, the selected articles were inspected in full text to assess their definitive eligibility. The decisions to remove an article or not were resolved between the two researchers after a deliberative process.

As additional selection sources, multiple reference lists of articles relevant to the topic of air pollution and quality of life were reviewed and literature was consulted with experts on topics dealing with environmental pollution.

2.4. Data extraction and plan of analysis

Initially, basic data were collected from each article, such as country of origin, study approach (qualitative, quantitative, or mixed), study design, size and sociodemographic characteristics of the sample, type of air pollution considered and presence of control variables for the case of the quantitative studies.

Then, a qualitative narrative synthesis was done to summarize the main findings of the selected studies, as well as the pending

main challenges. Narrative synthesis is a process that involves extracting and categorizing characteristics and outcomes from articles with diverse approaches and designs, whether quantitative or qualitative, to organize the main findings and conclusions of the studies (Popay *et al.* 2006). For this systematic review, the narrative synthesis was divided into three steps: *(i)* categorization of articles in common topics, *(ii)* analysis of the main findings in each category, and *(iii)* general synthesis of the findings of the selected studies.

3 Results

3.1. Selected studies

The PRISMA-P flow chart provided in Figure 1 describes the article selection process of this systematic review. The results of the systematic search in the 4 selected databases yielded a total of 311 articles. To these, 7 articles were added, identified by a review of reference lists from relevant articles and literature consultation with experts, giving a total of 318 articles. From this total, 110 duplicates were eliminated, leaving 208 articles for analysis. Of these, 184 were excluded by the title or abstract, whereas 7 were excluded after reading the full text. Finally, this systematic review included a total of 17 articles for the qualitative synthesis.

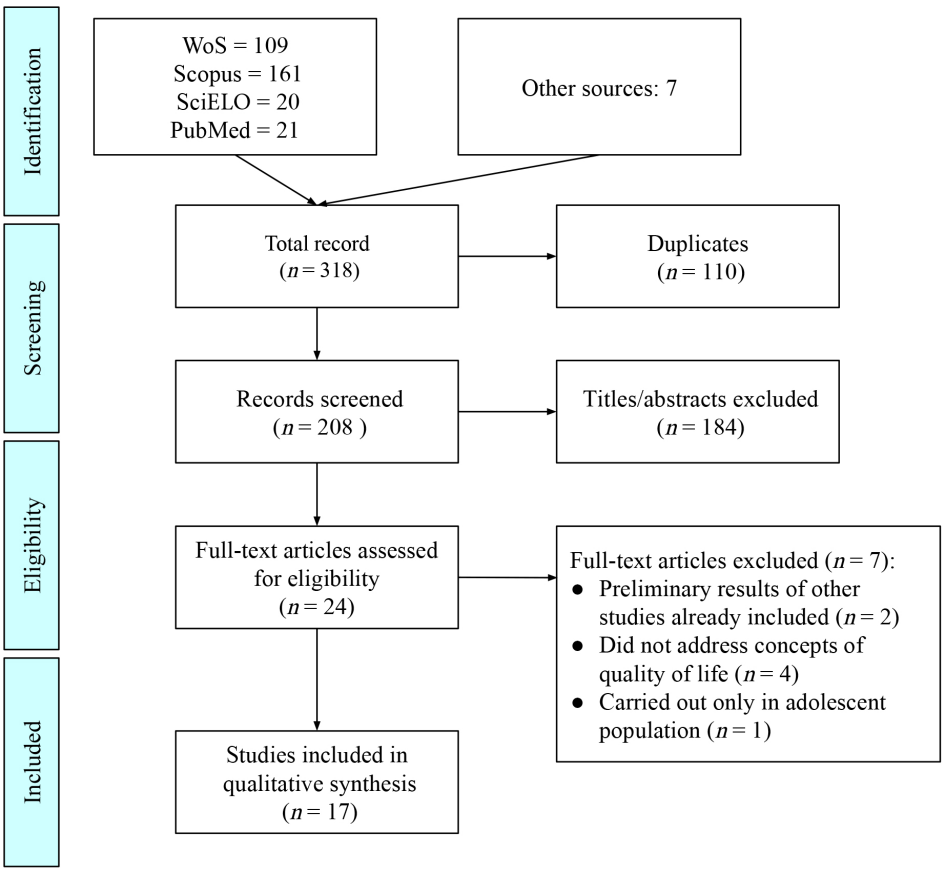

Figure 1

PRISMA flow charge for article selection

3.2. Characteristics of the selected studies

The characteristics of the selected studies for this systematic review are summarized in Table 1. The reviewed articles were published between 1986 and 2021. However, 70 % of the selected articles were published in the last five years prior to this review (2017-2021), demonstrating a remarkable increase in the latest period. Regarding the country of origin, the studies are distributed across four Latin American countries: Brazil (9), Chile (4), Colombia (2) and Mexico (2). In relation to the study design, 16 articles worked from a quantitative approach with a cross-sectional non-experimental design (Hernández *et al.* 2014), whereas only one study worked from a qualitative approach with semi-structured interviews. Table 2 shows the central objective of each study and their main findings related to the aim of this systematic review.

Authors/year	Country	Method[a]	Sample	Measured pollutant (main origin)	Concept regarding well-being	Control variables
Bertanha 2021	Brazil	Qualitative with semi-structured interviews	30 residents of Fercal, Brasilia	Total suspended particulate (TSP) (industries)	Feelings of frustration, annoyance, and distrust	–
Machado *et al.* 2021	Brazil and France	Non-experimental cross-sectional descriptive	205 women and 310 men resident in Vitoria (518 people in France)	PM_{10} (industries)	Annoyance	Sex, age, occupation, education level, presence of diseases in the home, sources of pollution, seasonal variables, among others
Ahumada and Iturra 2021	Chile	Non-experimental cross-sectional correlational	22,202 residents from 305 different cities between 15-65 years (*M* = 40.9; *SD* = 11.7)	$PM_{2.5}$ (wood combustion in general)	Subjective well-being	Sex, age, marital status, education level, children, belonging to an indigenous people, income, hours worked, services in the city (temperature, level of employability, crime, others)
Da Silva *et al.* 2020	Brazil	Non-experimental cross-sectional correlational	5397 cases in Curitiba	NO_2, SO_2, O_3, PM_{10} (traffic)	Hospital admissions due to mental and behavioral disorders (section F00-F09 of the ICD 10). This includes depression and anxiety, due to organic causes	Day of the week, relative humidity

Authors/year	Country	Method[a]	Sample	Measured pollutant (main origin)	Concept regarding well-being	Control variables
Astudillo *et al.* 2019	Mexico	Non-experimental cross-sectional correlational	–	NO_2, SO_2, O_3, PM_{10} and $PM_{2.5}$ (traffic and industries)	Suicide	Temperature, humidity
Boso *et al.* 2019	Country	Non-experimental cross-sectional correlational	191 men and 298 women from 18 to 89 years (*M* = 43.0; *SD* = 18.6)	Perception of air pollution (residential combustion of wood)	Anguish, anger, and discomfort	–
García *et al.* 2019	Mexico	Non-experimental cross-sectional correlational	174 residents of Talpa de Allende from 14 to 88 years (*M* = 32.4; *SD* = 17.2)	Perception of the air quality (not specified)	Perceived quality of life	–
Machado *et al.* 2020	Brazil	Non-experimental cross-sectional correlational	220 residents of Vitoria over 16 years	PM_{10}, total suspended particulate (TSP) and SPM (industries and traffic)	Annoyance	–
Mendoza *et al.* 2019	Chile	Non-experimental cross-sectional correlational	37,000+ residents in 70 municipalities	PM_{10} and $PM_{2.5}$ (not specified)	Satisfaction with life	Income, age, sex, marital status, ethnicity, nationality, level of studies, evaluation of health, job situation, religion, residence, temperature, precipitation, among others
Fernández-Niño *et al.* 2018	Colombia	Non-experimental cross-sectional correlational	1942 cases in 4 cities: Bogota, Medellin, Cali, and Bucaramanga	NO_2, SO_2, CO, O_3, PM_{10} and $PM_{2.5}$ (not specified)	Suicide	Temperature, humidity, precipitation, holidays
Machado *et al.* 2018	Brazil	Non-experimental cross-sectional correlational	130 residents in 6 sub-regions of Vitoria	Sedimented particulate matter (SPM) (industries and traffic)	Annoyance	–
Robledo-Martínez *et al.* 2017	Colombia	Non-experimental cross-sectional correlational	1131 residents in 11 municipalities	Exposure to air pollution due to living near a coal mining (industries)	Quality of life with dimensions of physical, psychological health, social relations, and environment	–
Melo *et al.* 2015	Brazil and France	Non-experimental cross-sectional descriptive	205 women and 310 men resident in Vitoria (518 people in France)	PM_{10} (industries and traffic)	Annoyance	–

Authors/year	Country	Method[a]	Sample	Measured pollutant (main origin)	Concept regarding well-being	Control variables
Zeigelboim *et al.* 2015	Brazil	Non-experimental cross-sectional descriptive	30 men between 33 and 67 years (*M* = 49; *SD* = 8.5)	Carbon monoxide (CO) (industries)	Depression and anxiety	–
Salgueiro *et al.* 2009	Brazil	Non-experimental cross-sectional correlational	8 men and 2 women from 23 to 52 years (*M* = 32.5; *DS* = 8.5)	Mercury vapor (industries)	Symptoms of depression and anxiety	–
Zachi *et al.* 2007	Brazil	Non-experimental cross-sectional correlational	34 workers in a fluorescent lamp factory and 32 employees at the University of São Paulo. Ages from 33 to 54 years (*M* = 41.5; *SD* = 6.1)	Mercury vapor (industries)	Symptoms of depression and anxiety	–
Larraín Navarro and Simpson-Housley 1986	Chile	Non-experimental cross-sectional correlational	63 men and 37 women in 5 communes in Santiago	Perception of level of danger and concern for air pollution (industries and traffic)	Anxiety personality traits	–

[a] Research design classification by Hernández *et al.* (2014).

Table 1

General characteristics of the selected articles

Authors, year	Research objective	Main findings regarding the objective of this review
Bertanha 2021	To analyze how the residents of Fercal (Brazil) cope with the air pollution, due to TPS in their daily lives	Feelings of frustration are reported regarding the problem of the air pollution, as well as distrust of local and regional authorities, due to a deficient monitoring of the pollutants generated by the cement industries in the area. There are also feelings of hopelessness after more than five decades with no changes in this situation
Machado *et al.* 2021	To analyze and compare the relations between determining qualitative variables of the problems, caused by air pollution	There is a relation between the level of annoyance produced by the pollution and the perception of the relevance of air, perception of risk to health due to pollution, evaluation of the air quality and perceived air pollution. Women, older adults, retirees and the unemployed, as well as people with university studies, are the ones most annoyed by air pollution
Ahumada and Iturra 2021	To evaluate the economic impact of air quality on subjective well-being in Chile from the approach of satisfaction with life	A negative impact of air pollution by $PM_{2.5}$ and subjective well-being is observed, even when controlling for sociodemographic variables and city services
Da Silva *et al.* 2020	To evaluate the association between daily concentrations of air pollutants and weather variables with hospital admissions for mental and behavioral disorders in Curitiba (Brazil)	There is a significant association between air pollution and hospitalization for mental and behavioral disorders. The combination between high temperatures and pollution affected men more than women, except in young groups. On the other hand, adults see themselves more affected by the pollutants, especially women
Astudillo *et al.* 2019	To evaluate the association between air quality and record of daily suicides in Mexico City between 2000 and 2016	No relation was found between the concentration of the pollutants considered and the daily suicide count for men and women between 2000 and 2016

Authors, year	Research objective	Main findings regarding the objective of this review
Boso *et al.* 2019	To explore differentiated profiles on the perception of air quality based on attitudinal variables, sociodemographic variables and self-protection behaviors reported	There are three differentiated perception profiles. The «conscious» profile are people who have a very bad perception of the air quality, high scores in negative emotions resulting from the pollution such as anguish, anger, and discomfort, in addition to a high perception of risk and concern for the harmful effects of air pollution on health On the other hand, the «resigned» and «accustomed» perception profiles have low scores in negative emotions
García *et al.* 2019	To learn the environmental, social, demographic, and economic factors that affect perceptions of environmental conflicts in Talpa de Allende and how the perceived quality of life of the inhabitants is affected by these conflicts	As the perception of severity of the environmental conflicts increases, the perceived quality of life decreases significantly. The most important environmental problems related to quality of life are water scarcity and infrequent rain. Although air quality was identified as one of the main environmental conflicts, this did not have a significant relation with quality of life
Machado *et al.* 2020	To quantify the relation between perceived annoyance and concentration of particulate matter and to estimate the relative risk of experiencing annoyance	Analyses of relative risk show that the increased concentration of particulate matter (PM_{10}, TSP and SPM) contributes significantly to the probability of being annoyed by pollution. Thus, a significant correlation between particulate matter and levels of annoyance is reflected
Mendoza *et al.* 2019	To estimate the willingness to pay for the reduction of air pollution in Chilean cities using a non-traditional assessment model based on satisfaction with life	PM_{10} and $PM_{2.5}$ pollutants are significantly related to satisfaction with life, even controlling for multiple sociodemographic and climatological variables. This relation is maintained in both ordinary least squares and ordered probit models
Fernández-Niño *et al.* 2018	To explore the association between air pollutants and suicide rates in four Colombian cities adjusting for climatological variables and holidays	Initially, significant relations were found between the pollutants considered and suicide, but this relation disappears when the control variables of temperature, humidity or holidays are included, with in total number of suicides or number of suicides according to sex or age
Machado *et al.* 2018	To propose a guide to establish air quality standards based on the annoyance caused by sedimented particulate matter in industrialized metropolitan areas	There is a strong relation between sedimented particulate matter and feelings of annoyance. For every 1 g (m^2 30 days) that pollution increases, the inhabitants of Vitoria have 1.5 greater likelihood of feeling annoyed with the pollution
Robledo *et al.* 2017	To compare the perception of quality of life and environmental situation municipalities close to and far from the industrial mining activity of the Department of Boyaca	The people who live in contexts with high pollution levels have worse quality of life scores in the psychological and environmental domain than those who live in less contaminated contexts, especially older adults, and women
Melo *et al.* 2015	To analyze the annoyance caused by air pollution in two industrialized regions to identify determining variables of the perceived annoyance and to calculate the relative risk of experiencing this annoyance	More than 80 % of the participants report some degree of annoyance because of the air pollution. The determining variables of this annoyance are the perception of the importance of air quality, perceived risk of pollution, perception of air pollution due to dust, being female, occurrence of health problems and being over fifty-five years of age
Zeigelboim *et al.* 2015	To evaluate vestibular behavior in a sample of fishermen	A group of fishermen exposed to high noise and air pollution levels due to CO reports symptoms of depression and anxiety
Salgueiro *et al.* 2009	To evaluate whether there is a reduction in visual and neuropsychological abilities in workers with low exposure to mercury vapor	No differences were found in the depression and anxiety scores between the group exposed to mercury vapor and the control group. However, there was a correlation between the exposure time to the mercury vapor and high scores in depression
Zachi *et al.* 2007	To determine if exposure to elemental mercury vapor has a long-term effect on motor and cognitive functions, as well as on symptoms of depression and anxiety	The people exposed to mercury vapor had higher scores in depression and anxiety than those not exposed. The mercury concentration in urine measured a year after exposure correlates with symptoms of anxiety and changes to more irritable personality traits
Larraín Navarro and Simpson-Housley 1986	To evaluate the influence of personality dimensions on the perceptions or responses of the population to the issue of air pollution in Santiago (Chile)	People with anxiety personality traits tend to be more concerned about the problems of air pollution while at the same time taking more measures to fight this type of pollution

Table 2
Research objective and summary of the main findings of the selected articles

The selected studies address various aspects of quality of life and emotional well-being, including subjective well-being, satisfaction with life, perception of quality of life, feelings of annoyance or frustration, symptoms of depression, anxiety and even suicide. Considering these subjects, the narrative synthesis proposed in this review identifies three large thematic approaches: *a)* mental health, *b)* negative emotions, and *c)* subjective well-being.

3.2.1. Mental health

Out of the 17 reviewed articles, seven relate air pollution to the presence of mental health disorders or symptoms, making it the most common approach (41 %). These studies explore the impact on quality of life from a more clinical perspective. The first study recorded on this topic was by Larraín Navarro and Simpson-Housley (1986). This study works from personality theory, hypothesizing that anxiety personality traits are linked to increased concern and risk perception regarding air pollution. Two decades later, Zachi *et al.* (2007) and Salgueiro *et al.* (2009) invert this relation, proposing studies from a neuropsychological approach, which explore the relation between exposure to air pollution from mercury vapor and symptoms of depression and anxiety in middle-aged adult populations. On the one hand, Zachi *et al.* (2007) report that the mercury concentration in urine measured a year after exposure correlates with symptoms of anxiety and changes to more irritable personality traits, although no relation was found during exposure or the total time without exposure. In contrast, Salgueiro *et al.* (2009) found no differences in depression and anxiety levels between a group exposed to mercury vapor and another not exposed; however, there was a correlation between the exposure time to the mercury vapor and depression. Later, Zeigelboim *et al.* (2015), from an otoneurological point of view, also found higher levels of anxiety and depression in a sample of fishermen exposed to air pollution from carbon monoxide. Recently, Da Silva *et al.* (2020) have reported that exposure to various types of pollutants such as nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), coarse particulate matter (PM_{10}) and fine particulate matter ($PM_{2.5}$) are related to a higher number of hospital admissions due to mental and behavioral disorders. The combination between air pollution and temperature affected more men than women, except in the young groups, whereas when compared by age, adults are the most affected, especially women.

From another point of view, the time-series studies by Astudillo *et al.* (2019), and Fernández *et al.* (2018), point to a relation between air pollution and suicide rates. However, this relation disappears when controlling for other theoretically relevant variables to understand this behavior, such as temperature, precipitation levels, humidity, or the presence of holidays. Thus, they invite us to critically review those studies that have found a correlation between air pollution and

suicide without controlling for other variables, since their inferences could be based on a spurious relationship.

3.2.2. Negative emotions

On the other hand, 6 of the 17 selected articles (35 %) address the relation between air pollution and the presence of negative emotions. This line of research highlights the impact on individuals' emotions, which could potentially lead to emotional distress. Among these, the studies conducted in Brazil by Melo *et al.* (2015) and Machado *et al.* (2018, 2020, 2021) about perceived annoyance due to air pollution stand out. First, Melo *et al.* (2015) emphasize that more than 80 % of the participants in their study report some degree of annoyance because of air pollution due to particulate matter. Regression models established that the most determining variables of this annoyance are considering that air quality is important, having a high perception of risk from pollution, being female, having health problems, and being over fifty-five years of age. Later, Machado *et al.* (2021) performed a new analysis of the data from the study by Melo *et al.* (2015) and corroborated the findings using estimators of greater statistical power. This study introduces other control variables, finding that retirees or the unemployed and people with university studies report a greater perceived annoyance from air pollution. In this study, Machado *et al.* (2021) indicate the importance of considering the presence of contextual co-variables like climate or seasonal changes. Furthermore, Machado *et al.* (2018, 2020) prepare predictive models of relative risk, where they indicate that the concentrations of different measurements of pollutants from PM_{10}, SPM and TPS air significantly increase the likelihood of being annoyed by pollution. The 2018 study shows that, for every 1 g (m^2 30 days) that pollution particles increase, people are 1.5 more likely to feel annoyed by pollution, which is why they propose reducing the current norm of tolerable SPM from 14 g (m^2 30 days) to 5 g (m^2 30 days), to reduce the level of annoyance produced by this pollutant.

Using a qualitative study, Bertanha (2021) presents the case of a community in Brazil that is particularly exposed to the air pollution produced by two cement plants. From this experience, described as a «slow and omnipresent violence», the residents express their emotions of annoyance and frustration about a problem that has had no solution in decades. The study participants also recount feelings of distrust of the authorities. They doubt that the politicians in charge are going to take any measure on the matter, after more than sixty years of inaction, despite the complaints and information they have available on the harmful effects of the pollution on people's health. This study reflects that the experiences of air pollution can produce complex emotions not only towards the pollution itself but also as a response to the indifference that businessmen and government authorities

display in some contexts. Finally, the study by Boso *et al.* (2019) considers the presence of negative emotions added to other attitudinal variables to build perception profiles in terms of air pollution using a cluster analysis. The study discovered that there are three attitudinal profiles in a conurbation of southern Chile, saturated by smoke from firewood heaters and stoves. The «conscious» perception profile on air pollution is characterized as presenting a poor perception of air quality, high risk levels and high scores of anguish, anger, and discomfort due to pollution. This profile contrasts with those with a «resigned» perception profile, who have a negative evaluation of air quality and high-risk perception but report low scores of negative emotions. The third profile is the «accustomed», who usually overestimate air quality of their city, having a low perception of the risks that air pollution entails for their health and score low in negative emotions due to pollution.

3.2.3. Subjective well-being

Within the hedonic tradition of well-being, this review identified four studies (24 %) that specifically highlight the connection between air pollution and diverse aspects associated with the subjective perception of well-being. Mendoza *et al.* (2019) report a significant correlation of $PM_{2.5}$ and PM_{10} air pollution with satisfaction with life, which is maintained when controlling for multiple variables (age, sex, marital status, belonging to an indigenous people, being an immigrant, education level, number of people in the home, perception of health status, presence of chronic diseases, job status, possession of savings, religion, region of residence in Chile, poverty level in the region of residence, level of crime in the region, level of rain and temperature). Later, Ahumada and Iturra (2021) found results in the same direction and consistent with the work by Mendoza *et al.* (2019) controlling for an even wider range of variables (sex, age, marital status, level of schooling, ethnicity, children, number of hours working, perception of noise pollution, experience of thefts in the neighborhood, seasonal temperature, minimum and maximum monthly temperature, employment levels in the city of residence, crime level, presence of attractive buildings, and student-teacher ratio).

On the other hand, the study of Robledo *et al.* (2017) in Colombia compared two areas with high air pollution levels related to coal mining, with an area not affected by mining activity and whose main economic activity is agriculture. To achieve their objective, they used the WHOQOL-BREF instrument as a multidimensional measurement of quality-of-life perception that considers four domains: physical health, psychological health, social relations, and environment. Their findings indicate that people in polluted areas have a worse perception of quality of life —in psychological and environmental terms— than those who live in less polluted areas. No differences were found

in other dimensions of quality of life such as physical health or social relations. In their study, García *et al.* (2019), although they found a relation between perception of environmental conflicts and perception of quality of life among the residents of Talpa Allende in Mexico, there was no direct relation between the deterioration in air quality and the perception of quality of life. A possible explanation that the authors of the study outline is that the most relevant environmental problem for this population was water scarcity because it affects their daily lives most visibly. The people who participated gave less importance to other problems like the deterioration of air quality, cutting down trees, irresponsible tourism, forest fires or the loss of fauna in the forests. Thus, it can be understood that, while an environmental problem is not considered relevant (or the most relevant), it will hardly affect the quality of life of the people affected by it. It is also to be expected that, in scenarios with multiple environmental issues, the citizens will tend to prioritize those that generate a more direct and visible damage in their day-to-day lives.

4 Discussion

The aim of this review was to explore the effect of air pollution on well-being and quality of life in Latin American countries following the PRISMA-P guidelines. The 17 selected articles show three clear approaches to address these effects on well-being: *i)* mental health, *ii)* negative emotions, and *iii)* subjective well-being. From the mental health approach, evidence of relations between air pollution and symptoms of depression and anxiety has been found in several studies, which is consistent with studies conducted beyond the continent (Zhang *et al.* 2017, Van Den Bosch & Meyer-Lindenberg 2019). However, the studies analyzed in Latin America do not report significant associations between air pollution and suicide rates, putting at issue studies conducted in the Asian context (Ng *et al.* 2016, Kim *et al.* 2018). On the other hand, from the negative emotions approach, the selected studies have reported significant effects of air pollution on emotions such as annoyance, frustration, anguish, anger, and discomfort, which might reflect a state of emotional distress. The results on this line of research are consistent with the literature developed in other geographic contexts (Jacquemin *et al.* 2007, Llop *et al.* 2008). Finally, from the subjective well-being approach, there were significant relations with concepts like «perceived quality of life» or «satisfaction with life». These results are consistent with studies in China (Liao *et al.* 2015b, Yuan *et al.* 2018) and in several countries of the Global North, such as Australia (Ambrey *et al.* 2014), Canada (Barrington-Leigh & Behzadnejad 2017), the United States (Levinson 2012) or the United Kingdom (Dolan *et al.* 2016).

There is a paucity of studies that focus on the effects of air pollution on different aspects of well-being in Latin America. In most of the selected cases, the consideration of this relation was secondary or minimal, so the results and reported discussions do not reach the depth needed to advance towards an understanding of the nature of this complex relationship. Also, although studies like the one by Mendoza *et al.* (2019) or Ahumada and Iturra (2021) directly explore the relation between air pollution and satisfaction with life, they do so from an economic point of view, seeking to determine how much people are willing to pay to improve the air quality, omitting a more psychological or social view of the impact of pollution on people's mental health or quality of life. Our analysis indicates that air pollution negatively affects people's well-being, regardless of the source of the emissions. However, it's worth considering whether there are differences in the impact on those who emit pollution (such as wood stove or diesel vehicle users) versus those who do not. In the future, comparative research should explore the ways in which perceiving benefits from actions that generate air pollution can disturb the negative effects on well-being.

According to the United Nations, 8 out of every 10 people in Latin America and the Caribbean live in urban areas, being the second most urbanized region in the world (United Nations 2019). Despite the enormous development experienced in the last two decades, the Latin American continent continues to be characterized by an enormous inequality in the distribution of well-being (Jiménez 2015). The differences in access to water, management of solid waste or, in our case, good air quality are potential sources of psychological distress and impacts on the subjective well-being that have scarcely been addressed in the specialized literature. From what is reported in this review, the lack of studies that evaluate the harmful effects of air pollution on well-being in great capitals of Latin America like Bogota, Mexico City or Santiago de Chile, which have lived with this problem for decades, is remarkable. Even more noteworthy is the complete absence of studies in other multiple Latin American cities highly polluted by PM_{10} and $PM_{2.5}$, such as Quito, Lima, Monterrey, Guadalajara, Montevideo, or San Salvador, to name a few, which have exceeded the annual norm established by the WHO on multiple occasions (Garrido & Camargo 2012, Clean Air Institute 2013, Jorquera *et al.* 2019).

There are significant knowledge gaps in the Latin American context that future studies will have to address. From the line of emotional distress, studies on the effect of air pollution on perceived stress have not been found. Lundberg (1996) posits that air pollution can be experienced as an environmental stressor that causes distress among those exposed to its effects. It is relevant to add findings in this line, because even internationally there is no consensus in the literature on the relation between these two var-

iables. For example, Nuyts *et al.* (2019) found no relation between exposure to NO_2 and perceived stress in older adults in Belgium. However, Lamichhane *et al.* (2021) find this relation between exposure to pollution and prenatal maternal stress in South Korea, as do Zhang *et al.* (2021) in university students in China. Although efforts to study the effect of pollution on negative emotions in Latin America have been made, these studies have been mainly linked to emotions like «annoyance» (Melo *et al.* 2015, Machado *et al.* 2018, 2020, 2021), added to sporadic efforts on other emotions (Boso *et al.* 2019, Bertanha 2021). Yet this review found no studies on emotions such as fear, blame or hopelessness, as in other countries like the United States (Lal *et al.* 2020) or China (Xue *et al.* 2019).

From the line of well-being or quality of life, this review did not find any study with a eudaimonic perspective of well-being. Robledo *et al.* (2017) is the only study that comes close to this approach by using a quality-of-life measurement that includes the level of satisfaction with personal relations. However, an investigation into the effects of air pollution on other dimensions of psychological or eudaimonic well-being, like autonomy, purpose in life, personal growth or the dominance of the environment are still pending (Ryff & Keyes 1995). From Asia, some efforts are being made in this line; for example, a study by Gu *et al.* (2015) in Beijing (China) reports that the perception of polluted air is negatively related to hedonic subjective well-being but positively to eudaimonic well-being, increasing the purpose and meaning of life.

At a methodological level, the selected studies have certain limitations that need to be addressed to enhance the robustness of the findings in the Latin American literature regarding the link between air pollution and well-being. First, most of the selected studies present small samples and bivariate analyses of low statistical power. These factors increase the likelihood of committing a type II error, *i.e.,* of not rejecting a false hypothesis. Moreover, it is observed that not all the studies conducting multivariate analyses integrate or report the fulfillment of assumptions such as multicollinearity, homogeneity of variances or independence and normal distribution of the residuals. This is fundamental, as it makes it possible to know whether the collected data fit the proposed models (Casson & Farmer 2014). Second, except for the studies by Larraín Navarro and Simpson-Housley (1986), Salgueiro *et al.* (2009), Zachi *et al.* (2007) and Zeigelboim *et al.* (2015), most of the studies measure well-being variables using single-item surveys and not by means of validated measurement scales with suitable psychometric properties; for instance, we found no studies using the Satisfaction with Life Scale by Diener *et al.* (1985), the Subjective Happiness Scale by Lyubomirsky and Lepper (1999) or the Psychological Wellbeing Scale by Ryff (1989), just to name a few, all of which have been validated and tested in multiple Latin American

studies, showing adequate psychometric properties (Vera-Villarroel *et al.* 2011, Moyano *et al.* 2013, Padrós *et al.* 2015).

Most of the selected studies have a quantitative approach and a non-experimental cross-sectional design. In this sense, it is necessary to diversify to more robust study designs, either experimental, quasi-experimental or longitudinal that can corroborate and give greater robustness to the reported findings. Only one qualitative study was found (Bertanha 2012), which explores the emotions derived from living in a highly polluted area using the account and subjective experiences of its residents. This underscores the challenge of delving more deeply into people's subjectivity on the effect of air pollution on other aspects like their mood, satisfaction with life or perception of quality of life. This will afford a phenomenological understanding of the experience of well-being, making possible the emergence of topics not considered by the authors, but which are vitally important for the participants; for example, a qualitative study by Bush *et al.* (2001) was aimed to explore the residents' perception of health risk due to pollution in a highly industrialized area. However, from the interviews, it emerged that one of the worst consequences of pollution and industries is the social stigma produced about the place where they live. There are also examples of mixed methods as Lauwers *et al.* (2020) have proposed, whose qualitative results served to reinforce and deepen their initial findings through a survey on well-being.

The present study has some limitations inherent to most systematic reviews; for example, some relevant databases in the field of social sciences (*e.g.,* PsycINFO, or Academic Search Complete) were not included, which is why there may be more studies than those reported in this systematic review. However, this review made various deliberate efforts to try to capture the largest number of empirical studies that explore the relation between air pollution and well-being in Latin America, even if it was secondarily. Among these efforts are the inclusion of multiple synonyms of each term relating to well-being and the search in three of the largest scientific databases currently in existence (WoS, Scopus, and PubMed), as well as SciELO, which is the largest database in Spanish and one of most important in Latin America. Other search strategies were also incorporated, such as the review of reference listings and consultations with experts, or including articles written in the two most spoken languages on the continent (Spanish and Portuguese), in addition to English as an international language. Despite the level of rigor used in the search, very few studies were found that address this topic to a certain extent, and even fewer studies in the Latin-American context. This may be due to few studies being developed in this line or that these studies have not been published in high-impact journals indexed in databases like those analyzed in this review.

5
Conclusions

The present systematic review aimed to investigate the impact of air pollution on well-being and quality of life in Latin American countries, adhering to the rigorous PRISMA-P guidelines.

Thematic analysis of the selected studies resulted in three distinct categories: mental health, negative emotions, and subjective well-being. The findings of this review reveal that air pollution has a significantly detrimental impact on various components of well-being, including life satisfaction, subjective well-being, and perceived quality of life. Moreover, air pollution is associated with symptoms of depression or anxiety and negative emotions such as fear, anger, and frustration. Despite the available evidence, this review identifies significant empirical gaps that require attention in future research; for instance, most studies adopted cross-sectional designs, limiting their capacity to establish causal relationships. Furthermore, there is a dearth of studies that investigate the effects of specific pollutants or the consequences of air pollution on vulnerable populations, such as children and the elderly.

To summarize, our review sheds light on the profound impact of air pollution on well-being and quality of life in Latin American countries. It underscores the need for future research that employs rigorous methodologies, explores the effects of individual pollutants, and investigates the impact on marginalized populations. The results of such studies would be instrumental in informing policy and interventions aimed at mitigating the negative effects of air pollution on well-being in Latin America.

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