

# Impact of Environmental Noise Pollution on Adverse Childbirth Outcomes in Chile: A Risk Analysis

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Impacto de la contaminación acústica ambiental en los resultados adversos del parto en Chile: Un análisis de riesgo

## ABSTRACT

The global decline in birth rate, combined with increasing environmental noise, presents a significant public health challenge. The World Health Organization (WHO) has identified environmental noise as a risk factor for both maternal and neonatal health. In Chile, this trend mirrors global patterns, with rising levels of acoustic pollution and declining birth rates. **Aim:** To analyze the impact of environmental noise on low birth weight and prematurity in Chile during the period of 2018-2020. **Methods:** An ecological study was conducted analyzing secondary data on gestational health and environmental noise from the Metropolitan region, Valparaíso, and Biobío in Chile. The birth rate, prevalence of low birth weight (LBW) and prematurity (PTL), and levels of daytime and nighttime environmental noise were quantitatively described. The attributable population risk was estimated using previously adjusted relative risks. **Results:** The birth rate in Chile was 10.94 during the study period. An estimated 19,817 cases attributable to low birth weight and 3,055 premature births related to exposure to environmental noise during 2018-2020 were estimated. **Conclusions:** In Chile, daytime and nighttime environmental noise from vehicular traffic exceeded the dB levels established by the WHO international guidelines. This exposure represented a risk factor for the occurrence of low-birth-weight births, a condition that, along with the decrease in birth rate, poses an alarming public health problem, considering that low birth weight is one of the main causes of infant mortality in children under five years old worldwide.

**Keywords:** Acoustic pollution; Environmental pollution; Pregnancy.

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Funding: This study received no funding.

Conflict of Interest Statement: The author declares no conflicts of interest.

Received: August 25, 2025.  
Accepted: December 5, 2025.

### RESUMEN

La natalidad junto al ruido ambiental supone un alarmante problema de salud pública, debido a la disminución de la tasa de natalidad mundial, además el ruido ambiental ha sido descrito como un factor de riesgo para la salud gestacional y la del recién nacido descritas por la OMS. En Chile se ha descrito una situación similar a lo que ocurre en el mundo actual, además de registrar elevados índices de contaminación acústica. **Objetivo:** Analizar el impacto del ruido ambiental sobre el bajo peso al nacer y la prematuridad en Chile durante el período del 2018-2020. **Métodos:** Se llevó a cabo un estudio ecológico de análisis de data secundaria sobre salud gestacional y ruido ambiental de la región Metropolitana, de Valparaíso y del Biobío en Chile. Se describieron cuantitativamente la tasa de natalidad, la prevalencia de BPN y PP, y los niveles de ruido ambiental diurno y nocturno. Se estimó el riesgo atribuible poblacional utilizando riesgos relativos ajustados previamente. **Resultados:** La tasa de natalidad en Chile fue de 10,94, nacimientos por cada mil habitantes durante el período de estudio, con región Metropolitana concentrando el 42,6% de los partos. Se estimaron 19.817 casos atribuibles con nacimientos con bajo peso y 3.055 partos prematuros relacionados a la exposición a ruido ambiental durante el 2018-2020. **Conclusiones:** En Chile el ruido ambiental diurno y nocturno por tráfico de rodados superó los dB establecidos por las guías internacionales de la OMS. Esta exposición representó un factor de riesgo para la ocurrencia de nacimientos con bajo peso, condición que, junto con la disminución de la natalidad, suponen un problema de salud pública alarmante, considerando que el bajo peso al nacer es una de las principales causas de mortalidad infantil en menores de cinco años a nivel mundial.

**Palabras clave:** Contaminación acústica; Contaminación ambiental; Embarazo.

The WHO<sup>1</sup>, defines noise as an underestimated threat that can generate various health problems in the short and long term, such as physiological, psychological, cardiovascular, metabolic alterations, and complications in pregnancy, including preterm labor (PTL) and low birth weight (LBW).

Various studies have evidenced the relationship between environmental acoustic pollution and the increased risk of prematurity and LBW. Although other environmental pollutants with similar effects

have also been identified<sup>2,3,4</sup>, a European cohort concluded that exposure to high decibels (dB) can increase embryonic size only in the early stages of gestation, without later alterations<sup>5</sup>. However, it is agreed that, depending on the source and the level of dB, noise can contribute to multiple gestational alterations, including spontaneous abortion<sup>4,6</sup>.

International environmental health guidelines establish acceptable noise limits: <65 dB during the

day and <55 dB at night<sup>7</sup>. It is estimated that more than 22 million adults are exposed to levels above 55 dB during the day due to vehicular traffic<sup>8</sup>. In Western Europe, traffic (vehicular, railway, and air) is the second cause of environmental threat, especially affecting vulnerable groups such as children, the elderly, chronically ill individuals, and pregnant women<sup>1,8</sup>.

According to the WHO<sup>9</sup>, environmental noise is considered a pollutant with “significant” effects on health, including low birth weight, preterm births, and congenital anomalies. This chronic pollution alters the autonomic nervous system, increasing concentrations of norepinephrine and cortisol, hormones associated with stress, generating a low-grade inflammatory state<sup>10</sup>.

Experimental studies in animals show that noise elevates levels of epinephrine and norepinephrine and decreases average fetal weight<sup>6</sup>, possibly due to changes in maternal blood pressure that reduce uteroplacental perfusion, directly affecting fetal growth.

In pregnant women, noise has also been linked to sleep disorders, a risk factor for preterm birth and low weight, as the latter is closely related to prematurity<sup>8</sup>. Preterm birth is considered to occur before 37 weeks of gestation<sup>11</sup>. Each year, 13.4 million premature children are born. In Chile, the rate increased from 6.2% in 1991 to 9.49% in 2021. Additionally, 7.93% of newborns present LBW. These conditions elevate the risk of chronic pathologies and alterations in cognitive and behavioral development<sup>12</sup>.

In Chile, environmental noise is the third most relevant environmental problem<sup>13</sup>. In Santiago, more than 20% of the population is exposed to daytime levels above 65 dB, with vehicular traffic being the main source of acoustic pollution<sup>14</sup>.

## Methods

### 2.1. Study Design

The design corresponded to an ecological analysis of secondary data, focused on the occurrence of LBW and PLT in women exposed to environmental noise from daytime and nighttime vehicular traffic in Chile during the period from 2018 to 2020.

### 2.2. Sources of Information

The study analyzed data from the National Health Survey (INE) on birth rates and female population density, and from the DEIS on maternal age and birth weight. Additionally, environmental noise levels (day and night) were obtained from the Ministry of the Environment (MMA), using data from 14 monitoring stations located in the Metropolitan Region, Valparaíso, and Biobío.

### 2.3. Data Analysis

A quantitative description of the demographic background related to birth rate and the causes of LBW and PLT in Chile in the years 2018, 2019 and 2020 was carried out. For each year, the global birth rate was calculated, as well as the regional birth rate corresponding to those regions that had environmental noise monitoring.

The calculation was performed using the formula:

$BR = (BI / P) \times 100$ , where BI is the total number of live births and P is the total population of women of reproductive age.

Subsequently, the prevalence of LBW and PLT in the study regions was determined, using the formula:

$Prevalence = (C / N) \times 100$ , where C is the number of cases associated with the cause under study and N is the total number of births in the studied region during the period from 2018 to 2020.

Using adjusted RR for exposure to environmental noise from vehicle traffic<sup>4</sup> (Table 1), PAR was calculated using the formula:

$PAR = Pe (RR e - 1) / [1 + Pe (RR e - 1)]$ , where Pe is the population exposed to environmental noise and RR is the relative risk.

Finally, the number of attributable cases (AC) of LBW and PLT associated with exposure to environmental noise was estimated using the formula:

$AC = VC \text{ Cases} \times PAR$ , where AC is the number of attributable cases, VC Cases corresponds to the observed frequency of LBW and PLT, and PAR is the population attributable risk. For this calculation, the maximum cutoff point was considered according to the guidelines established by the WHO<sup>8</sup>.

**Table 1.** Relative risk for environmental noise pollution for gestational causes.

Cause	RR due to environmental noise pollution	Lower limit (95%)	Upper limit (95%)
LBW	1.19	1.03	1.38
PTL	1.05	0.94	1.17

RR for causes of LBW and PTL due to environmental noise with 95% IC<sup>4</sup>.

#### 2.4. Analysis of environmental noise data

A quantitative description of the 14 monitoring stations for environmental noise due to vehicle traffic, located in RV, RM, and RVIII, was carried out. For each station, daily averages of daytime and nighttime dB were calculated during the period from 2018 to 2020.

#### 2.5. Biases and limitations of the study

The main bias identified was the ecological fallacy, as population groups analyzed may have varied significantly in their exposure to environmental noise pollution.

Confounding bias relates to individual risk factors in pregnant women that may influence LBW and PTL, including alcohol or drug use, systemic diseases, hypertension, and exposure to other pollutants (PM<sub>2.5</sub>, NO<sub>2</sub>, O<sub>3</sub>) or temperature changes. These factors were controlled using the methodology by Rockhill et al.<sup>15</sup>, applying their proposed equation 1:

A formula for multicategorical exposures provides an internally valid estimate when con-

**Equation 1.** Formula for the estimation of attributable fraction.

$$\sum_{i=0}^k pd_i \left( \frac{RR_i - 1}{RR_i} \right) = 1 - \sum_{i=0}^k \frac{pd_i}{RR_i}$$

founding is present and adjusted RR are used<sup>15</sup>. Here,  $pd$  represents the proportion of cases at the  $i$ -th exposure level, and  $RR$  compares that level to the unexposed group. This method is appropriate for adjusted, multicategorical exposure analyses.

The measurement bias was controlled using standardized monitoring stations validated by the MMA for the precise measurement of environmental noise.

The main limitations of the study relate to the availability of data from the consulted sources. In particular, the INE did not provide specific information regarding the LBW and PTL variables, so these data were obtained from the DEIS, which only reports information from public health services.

Finally, although environmental noise pollution has been associated with various physiological alterations, including sleep disturbances, this last variable was not addressed in the present study because the available information came from mediated models, which poses a relevant limitation.

#### 2.6. Ethical Implications

The study uses anonymized public data and involves no direct interaction or intervention with individuals, so ethical approval isn't required.

## Results

### 3.1. Birth Rate in Chile

In Chile, during the period from 2018 to

2020, there were a total of 626,898 births. Of these, 248,392 were from the RV, RM and RVIII (Table 2). In the same period, 42,913 births with low birth weight and 22,355 premature births were observed.

### 3.2. Environmental noise in Chile in the period of 2018-2020

The monitoring of environmental noise in Chile was carried out through 14 stations distributed in three regions. In the year 2018, there were 8 active stations, in 2019, with 10 stations and in 2020 with 14 stations. The distribution of the stations was mainly located in the RM with 10 stations, followed by the RV and the RVIII, with 2 stations each (Table 3).

Average dB of environmental noise in the regions of Chile (RV, RM and RVIII) that have environmental noise monitoring, for the period of 2018-2020.

Daily averages of environmental noise showed most stations exceeding the established threshold. Only Ñuñoa and Independencia recorded levels below 55 dB from 1:00 to 6:00, while Cerro

Navia, Concepción Centro, and Providencia did so from 1:00 to 5:00. The highest noise level was recorded at the Autopista Central station (Figure 1).

### 3.3. Association of Environmental Noise Impact on Gestational Morbidity in Chile

The prevalence of pregnant women who had low birth weight births was estimated and premature births, as reported in table 4.

The PAR was calculated using the adjusted RR<sup>4</sup>, corresponding to an RR of 1.19 (IC95% 1.03 – 1.38) for LBW and 1.05 (IC95% 0.94 – 1.17) for PTL. These values were applied to each year of the study period in the regions that have environmental noise monitoring (Table 5).

According to this methodology, a total of 19,817 cases attributable to BPN and 3,055 to PP were estimated because of exposure to environmental noise.

PAR considering the RR adjusted for pollution noise. The values correspond to the results at apply the proposed RR, considering the lower and upper limits according to the 95% CI.

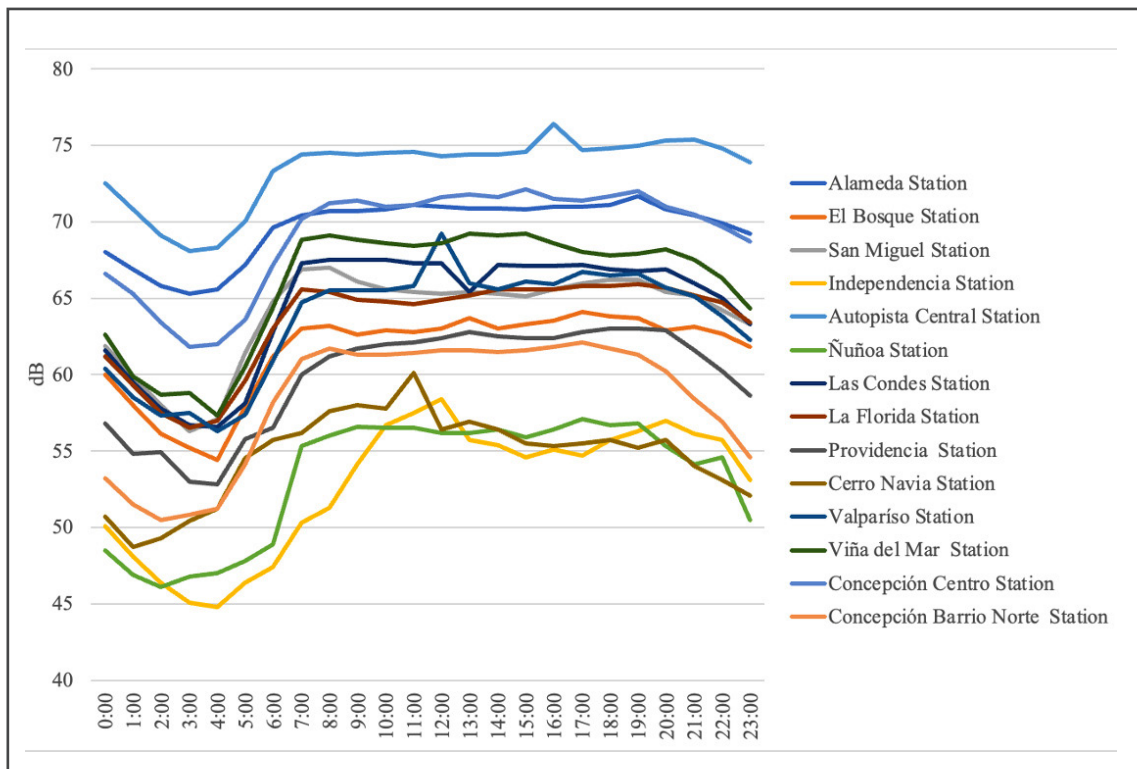
**Table 2.** Birthrate, LBW, and PTL in Chile during 2018-2020.

Year	Birth		Birthrate		LBW		PTL	
	2018	Global	221,731	Global	11.8	Regional	15,446	Regional
Regional		89,139	Regional	3.0				
2019	Global	210,188	Global	10.94	Regional	14,404	Regional	7,528
	Regional	83,645	Regional	2.8				
2020	Global	194,979	Global	10.1	Regional	13,063	Regional	6,805
	Regional	75,608	Regional	3.0				

Birth background in Chile for each year of the study period with the global birth rate (Chile) and regional (RV, RM and RVIII).

**Table 3.** dB of environmental noise in the regions of Chile during 2018-2020.

Year	Location	Daytime dB	Nighttime dB
2018	RV	66.7	57.2
	RM	69.7	66.1
	RVIII	66.2	56.8
2019	RV	68.2	58.5
	RM	70	65.6
	RVIII	66.1	56.7
2020	RV	67.7	58.5
	RM	64.2	57.2
	RVIII	66	56.7



**Figure 1:** Record of dB of environmental noise in Chile, during 2018-2020. Environmental Noise from Vehicle Traffic Recorded at the 14 Monitoring Stations in the RV, RM and RVIII.

**Table 4.** Prevalence of LBW and PLT in women exposed to environmental noise in Chile.

Year	Prevalence LBW		Prevalence PTL	
	2018	RV	187	RV
RM		22	RM	12
RVIII		140	RVIII	73
2019	RV	189	RV	99
	RM	22	RM	12
	RVIII	134	RVIII	76
2020	RV	181	RV	94
	RM	22	RM	12
	RVIII	131	RVIII	68

Estimation of prevalence of pregnant women with LBW and PTL in the RV, RM and RVIII of Chile who have environmental noise monitoring, for the study period.

**Table 5.** Population attributable risk for the causes of LBW and PTL in pregnant women exposed to environmental noise in Chile during 2018-2020.

Region	Year	PAR		Lower limit	Upper limit
		LBW	PTL		
RV	2018	LBW	3,580	665	7,259
		PTL	592	-490	1,772
	2019	LBW	3,603	669	7,306
		PTL	598	-498	1,793
	2020	LBW	3,462	647	7,024
		PTL	577	-472	1,722
RM	2018	LBW	320	169	978
		PTL	62.4	25	312
	2019	LBW	538	169	976
		PTL	62.7	25	313
	2020	LBW	544	170	987
		PTL	63	24	315
RVIII	2018	LBW	2,685	524	5,469
		PTL	369	-343	1,356
	2019	LBW	2,571	506	5,241
		PTL	384	-360	1,404
	2020	LBW	2,515	497	5,130
		PTL	347	-317	1,280

## Discussion

The decrease in the global birth rate has become a significant public health problem, due to the marked decline observed in recent decades<sup>16,17</sup>. In Chile, the trend is similar, as evidenced by census data since the mid-20th century, which shows fluctuating birth figures over time. During the 2010s, the birth rate was 14.36 births per thousand inhabitants<sup>18</sup>. However, in the study period (2018-2020), this rate decreased to 10.94 per thousand, with a drop of 8.7% observed in 2020 compared to 2018. The Metropolitan Region concentrated 42.6% of the births during this period, which is directly related to the high territorial and population concentration in that area<sup>19</sup>.

Along with the decrease in the birth rate, another growing problem in Chile has been prematurity. Since the 1990s, when a prevalence of 6.2% was reported, this figure has been increasing, reaching 8.6% in 2017 and 9.42% in 2020. This situation resembles the global prevalence, which during the same period was 10%<sup>20</sup>.

Another critical factor associated with birth is the weight of the newborn. Low birth weight (LBW) is directly related to gestational age and, primarily, to prematurity. Both conditions –LBW and preterm labor (PTL)– are considered important risk factors for neonatal health and are related to complications such as respiratory distress syndrome, sepsis, intraventricular hemorrhage, necrotizing enterocolitis, hypoglycemia, hyperbilirubinemia, and feeding difficulties<sup>18,21,22,23</sup>. Additionally, they can lead to medium-term deficits in growth, cerebral palsy, and, to a lesser extent, cognitive alterations, emotional and learning difficulties, as well as behavioral disorders such as anxiety and depression<sup>19,20</sup>. According to the WHO, the main cause of mortality in children under five years old, especially during the first year of life, is prematurity, which generates a high burden of disease and disability<sup>21</sup>.

Gestational health can be influenced by internal factors, such as maternal or fetal conditions, and by external factors, such as environmental pollutants. Among these last ones, atmospheric pollution, especially from fine particulate matter (PM<sub>2.5</sub>)<sup>3</sup>, and environmental noise pollution stand

out. The latter varies according to the emitting source and exposure conditions. Various studies have shown that both occupational noise and that from air and vehicular traffic can generate alterations in childbirth, and even cause spontaneous abortions<sup>3,5,6</sup>.

Environmental noise has been characterized as a stress factor that affects the hypothalamic-pituitary-adrenal axis, generating a significant increase in cortisol in the body, especially in pregnant women, which can also alter sleep patterns<sup>8</sup>. A study conducted in Spain<sup>5</sup> revealed that women exposed to environmental noise from vehicular and railway traffic experienced an increase in embryonic size in the early stages of gestation, compared to unexposed women. However, this finding may not reflect the Chilean reality, as the levels of exposure in that study were approximately 54 dB, while in Chile, during the studied period, average levels were recorded to be over 10 dB higher.

The WHO guidelines<sup>22</sup> establish acceptable noise levels according to the type of emitting source. In Chile, although there are multiple sources of noise, only that from vehicular traffic is monitored<sup>14</sup>. During the study period, the average daytime and nighttime noise levels exceeded the limits established by both the WHO and Chilean legislation (Supreme Decree N°38/2011), which sets a maximum of 55 dB during the day and 45 dB at night in residential areas. However, all monitoring stations showed levels above these limits.

Given that there is no specific RR for exposure to environmental noise in pregnant women in Chile, an adjusted RR from the international literature was used<sup>4</sup>, corresponding to women exposed to levels of up to 80 dB. Based on this value, it was estimated that the RV had the highest number of attributable cases of LBW throughout the analyzed period, followed by the RVIII. In contrast, the RM, despite concentrating the highest number of births, presented the lowest estimated causal relationship.

Regarding attributable cases of prematurity, a national estimated prevalence of 9% was used, showing a correlation with regional distribution. Both RV and RVIII had the highest values of at-

tributable cases. However, these estimates may be influenced using an RR adjusted to contexts different from the Chilean one and by the limitations of the ecological design, which does not consider the individual characteristics of the population.

Considering this situation, it is essential to develop cohort studies in Chile that allow for the establishment of specific relative risks for the country, considering its different sources of emission. This information would be key to formulating effective public policies in the management of environmental noise, which could translate into the prevention of up to three thousand premature births and more than nineteen thousand cases of low birth weight.

### Acknowledgements

The authors thank Dr. Patricia Matus for her support and Mr. Igor Valdebenito for managing environmental noise data from Chile's Ministry of Environment.

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