Impact of Air Quality on Infant Mortality: Evidence from India

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Abstract

According to the World Health Organisation (WHO), air pollution kills approximately seven million people per year around the world. The link between air pollution and a variety of unfavourable health consequences is becoming increasingly clear, but its negative effect on infants is less well understood. This study focuses on the impact of air quality on infant mortality in developing countries, with a particular focus on India. It is a state-level analysis but it also includes a subsample analysis based on the area of residence, i.e., urban or rural. This topic is important because air pollution and infant mortality adversely impact a nation's economy. This study uses an empirical model to establish the effect of air quality on infant mortality. Overall, it is found that the SO2 rate does not significantly affect the age of death of the child. The NO2 rate in a state, though, does negatively affect the age of death of an infant. An increase in the NO2 rate by one is expected to decrease the life of the infant by 0.26 days. In rural regions, an increase in the NO2 rate by one is expected to decrease the life of the infant by 0.31 days. Meaning that the higher the pollution in the air, the younger the infant is at death. Further, it is also found that if the mother smokes and there is a unit increase in the SO2 rate, the infant is expected to live for ten days less. This is a very unique and important result.

Introduction

Air pollution is defined as the release of pollutants into the atmosphere that are harmful to human health and the environment as a whole. According to the World Health Organization (WHO), air pollution kills approximately seven million people per year around the world. Nine out of ten people now breathe air that exceeds the WHO's pollution guideline levels, with individuals in low- and middle-income nations bearing the brunt of the burden (Deshpande, 2021).

Depending on the different types of air pollutants, the effects on the human body also vary. The time and intensity of exposure and other factors, such as a person's personal health risks and the cumulative effects of various pollutants or stressors, are also taken into account (Deshpande, 2021).

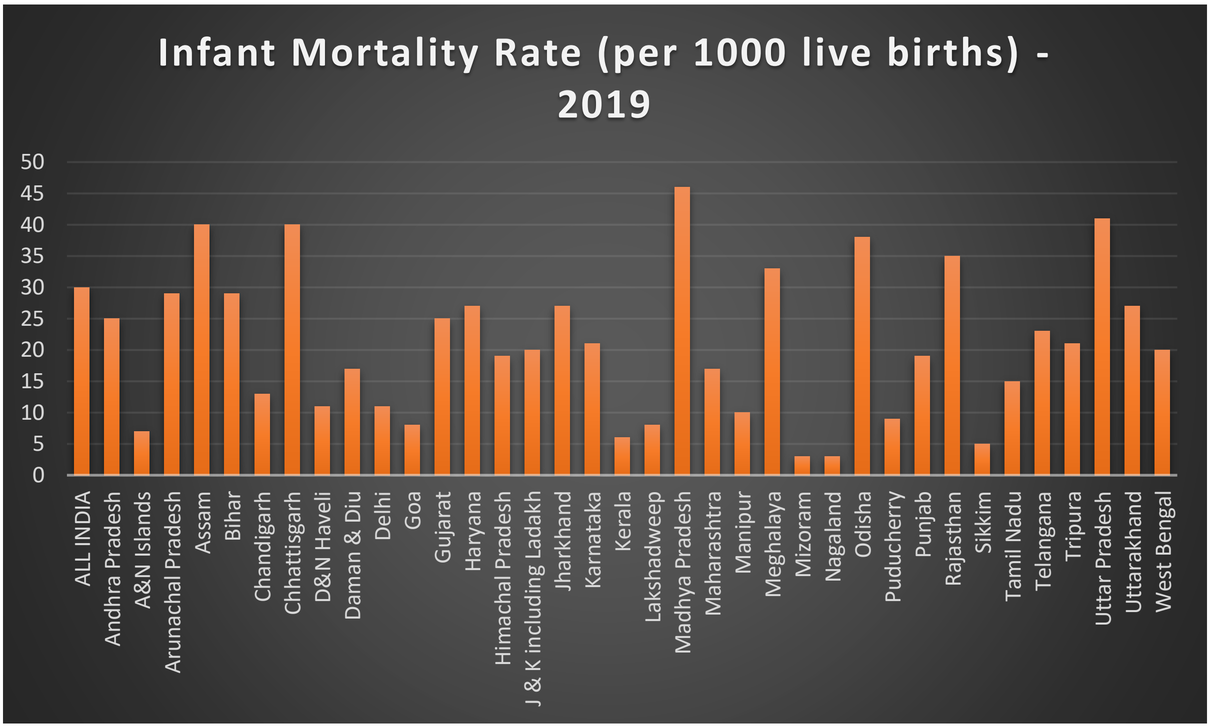
According to research from 2019, India has nine of the world's ten most polluted cities, but with 200 PM2.5 monitoring sites in operation between 2010 and 2016, India's air quality monitor density—about 0.14 monitors per million people—is lower than China (1.2), the United States of America (3.4), Japan (0.5), and Brazil (1.8) (Deshpande, 2021).

According to studies, India requires 1,600 to 4,000 air quality monitors due to its size, population, and worsening air pollution, but only has 804 as of September 16, 2021, most of which are centred in urban areas. According to experts, this inhibits India from knowing the exact degree, scale, and geographic distribution of certain contaminants, as well as limiting the government's capacity to take preventative public health actions (Deshpande, 2021).

As a result, India is unaware of the extent to which pollutants such as sulphur dioxide (SO2), nitrous dioxide (NO2), respirable PM 10, finer particulate matter or PM 2.5, lead, carbon monoxide (CO), and ammonia are present. According to the World Health

Organization, chronic exposure to these pollutants increases the chance of acquiring conditions such as cardiovascular and respiratory diseases, as well as lung cancer (Deshpande, 2021).

Infant mortality occurs when a child dies before reaching his or her first birthday. The number of newborn deaths per 1,000 live births is known as the infant mortality rate. The infant mortality rate is an essential indicator of a society's general health, in addition to providing crucial information regarding maternal and baby health (CDC, 2021).



Source: Ministry of Health & Family Welfare (2019)

This study focuses on the impact of air quality on infant mortality in developing countries, with a particular focus on India. The study's impetus derives from a Stanford study that found that greater air pollution is linked to higher newborn death rates. According to the study, dust and climate change may be to blame for the spike in infant mortality in some areas, and tackling these issues could help reduce infant mortality rates.

Children under the age of five are especially exposed to particulate matter, or microscopic airborne particles, which result from pollution. These air pollutants, as well as seemingly undetectable dust particles, have been linked to a variety of health issues in infants. Low birth weight and development impairment or retardation throughout the first year of life are examples of these health issues. As children get older, exposure to air pollution affects their overall life expectancy. According to several studies, people growing up in areas with high air particle matter had a 4- to 5-year shorter life expectancy (WHO, 2022).

Quantifying the true impact of air pollution on health is one of the crucial ways to lower the global ill-health burden. One such indicator is infant mortality. According to researchers, the situation is paradoxical. Because of increased employment and access to healthcare, infant mortality is reduced in both developing and developed countries. On the other hand, because their development is determined by industrialisation, which leads to higher levels of air pollution, these countries are also among the most polluted.

Economic Impact of Infant Mortality and Air Pollution

This topic is important because air pollution and infant mortality adversely impact a nation's economy. This is especially true in the case of India, a developing country. In India, air pollution was responsible for 16.7 million fatalities in 2019, accounting for 17.8% of the country's total mortality. The bulk of these fatalities was caused by indoor and outdoor particulate matter pollution. From 1990 to 2019, the mortality rate owing to residential air pollution reduced by 64.2%, but the death rate due to ambient particulate matter pollution grew by 115.3% and that due to ambient ozone pollution climbed by 139.2%. In India, economic losses resulting from premature mortality and sickness due to air pollution totalled

US$288 billion and $80 billion, respectively, in 2019. This overall loss of $368.5 billion represented 13.6 percent of India's GDP (Pandey et al., 2021).

The economic loss as a percentage of state GDP ranged 3.2 times amongst states, ranging from 0.67 percent to 2.15 percent, with the lowest per-capita GDP states of Bihar, Rajasthan, Uttar Pradesh, Madhya Pradesh, and Chhattisgarh experiencing the most loss. In 2019, Delhi had the biggest per-capita economic loss owing to air pollution, followed by Haryana, with a 5.4 times difference between the two states (Pandey et al., 2021).

In some nations, the infant mortality rate and real per capita GDP have a strong and negative association, according to Erdogan et al. As a result, it can be inferred that as nations got richer and more powerful, their newborn mortality rates declined, and new levels of strategic thinking, which would develop inventive solutions, played a key part in lowering infant mortality rates and increasing their economic strength (2013).

Literature Review

Although the harmful effects of air pollution and the impact of air quality on human health have been widely discussed - the amount of literature and research on the impact on infant mortality specifically leaves a gap to be further explored. With India being one of the most polluted countries in the world, no studies have currently focused on this topic from an Indian perspective. However, the following studies have explored the relationship between air quality and infant mortality in other parts of the world - which serve as useful references as we try to empirically examine the intricacies of this relationship in the Indian subcontinent. Further, instead of using infant mortality as a binary indicator, this study looks into the uses of data on the age of death of the infant (in days) to see how that would be impacted by air quality changes.

Kotecha et al. (2019) aimed to investigate the relationship between air quality on mortality as a whole - specifically to understand whether air pollution differently affects or causes neonatal or infant mortality. Using a quantile regression empirical model with variables such as NO2, SO2 & PM10 as proxies for air quality (control variables included deprivation, birth weight, maternal age, sex and multiple births), the study found that increased exposure to SO2 specifically increased the incidence of infant mortality, while all three proxies were significantly associated with neonatal death rates.

Heft-Neal et al. (2018) discussed the robust relationship between air quality and infant mortality in the arid and developing region of Africa, which serves as a close reference point for our study as India is also a developing country. The study elaborates on how poor air quality is associated with mortality risk - and builds on these assumptions by combining information from household surveys on the location and timing of almost 1 million births in Sub-Saharan Africa with satellite-based estimates of exposure to ambient respirable particulate matter (PM2.5 is used as a proxy for air quality). The study's major finding was that an increase in 10 $\mu g/m^3$ in PM2.5 concentration levels is associated with a 9% rise in infant mortality - a result that has persisted for over 15 years. The study concludes with a recommendation that reduced PM2.5 levels are likely to have health advantages to newborns that are greater than the majority of well-known health interventions.

A third study by Armstrong et al. (2007) analysed daily time series data of air pollution and all infant deaths for ten years across ten major cities of England: Sheffield, Bristol, Leeds, London, Liverpool, Nottingham, Manchester, Middlesbrough, Newcastle, and Birmingham. This study again found similar results wherein a majority of contaminants studied had low links with newborn mortality. The exception was sulphur dioxide (SO2), which had an RR of 1.02 (95 percent CI 1.01 to 1.04) in all baby fatalities with a 10 $\mu g/m^3$ increase.

Buka et al. (2006) build on the foundation of the adverse impacts of air quality on respiratory outcomes such as asthma, deficits in lung growth and other respiratory symptoms in children - by investigating mortality. The paper studies six major air pollutants mainly - O3, PM, NO2, SO2, CO, & PB, and conducts an empirical study based on the geographic location of Canada. It finds that ambient air pollution can be linked with increased mortality in children - with a special emphasis on the impact of particulate matter (PM) & SO2.

Finally, an extremely interesting study by Currie (2016) researches the impact of air quality on infant health by specifically distinguishing between high levels and low levels of air pollution. With a hypothesis that states that even relatively low levels of pollution can adversely affect an infant's health - the research was inconclusive in terms of finding a direct link between lower and higher levels but maintains a positive correlation relationship between CO & SO2 (the main proxies for air quality) and infant mortality.

Hypothesis

Based on our literature review, our initial hypothesis maintains the assumption that air quality (in the form of pollution) adversely impacts the health of an infant. Moreover, we believe that air pollution can affect the infant mortality rate to at least some extent - if not significantly. Our empirical study will serve to explore this research question. Lastly, based on a majority of the studies published across other parts of the world, we believe SO2 to be a significant air pollution proxy that impacts infant mortality.

Data description

This paper uses NFHS 2015-16 data for all data on infant mortality and mother and child's health. The National Family Health Survey (NFHS-4) for 2015-16 is the fourth in the series and offers data on India's population, health, and nutrition for each state and union territory. The Ministry of Health and Family Welfare (MoHFW) of the Government of India was responsible for all four NFHS surveys. The 2015-16 National Family Health Survey's main goal is to collect vital information on health and family welfare, as well as information on new difficulties in these areas (DHS Program, 2017).

The variables on air quality have been sourced from a publicly available dataset on GitHub. It contains data on sulphur dioxide (SO_2) rates, nitrogen dioxide (NO_2) rates and Suspended Particulate Matter (SPM) rates. The data was available for various air quality monitoring laboratories. This data was then averaged out state-wise to use in the model. The states Tripura, Andaman and Nicobar Islands, and Lakshadweep have been eliminated from our analysis as data on air quality was not available, but due to their small size, they should not change the results drastically.

Table 1: Variables

Variable	**Description**
infantdeath	Age at death of infant (in days)
stateso2	Average of SO2 levels in state
stateno2	Average of NO2 levels in state
statespm	Average of SPM levels in state
Residence	Dummy=1 if urban and =0 if rural
educ	Highest year of education
impwatersource	Dummy=1 if water sourced from an improved water source
cig	Dummy=1 if smokes cigarettes and =0 otherwise
sex	Dummy=1 if male and =0 if female
birthwgt	Birth weight in grams
alc	Dummy=1 if drinks alcohol and =0 otherwise

so2cig	Interaction between stateso2 and cig

(*Source: Author's own)*

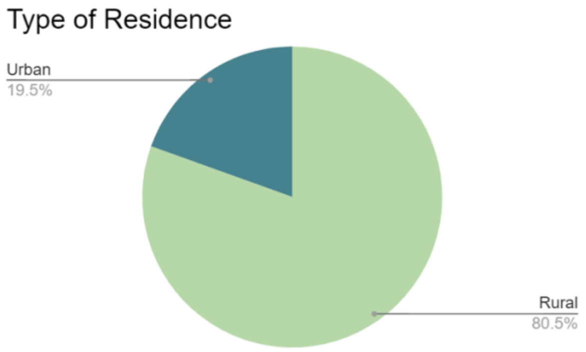
The variable 'impwatersource' refers to whether or not the household sources their water from an improved water source. Improved drinking-water sources are ones that are more likely to be free of external pollution, particularly faecal matter. Household connections, boreholes, communal standpipes, protected drilled wells, safeguarded springs, and rainwater collecting are all examples of improved water sources (*Improved sanitation…,* n.d.). The other variables are straightforward.

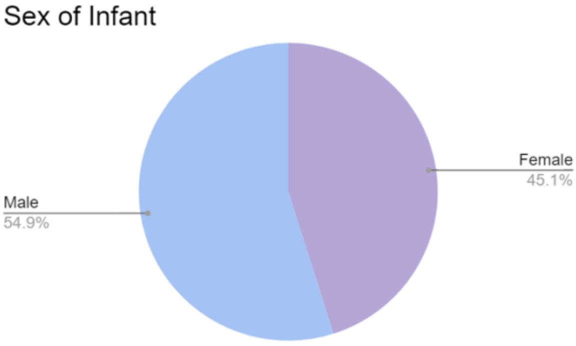
Table 2: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
infantdeath	71,813	65.55661	113.6478	0	365
stateso2	71,119	15.46533	7.362593	2	33.3
stateno2	71,119	26.07663	12.39344	4.5	56.2
statespm	58,754	206.3255	125.1051	25	614
residence	71,813	0.1953268	0.3964548	0	1
impwatersource	71,813	0.8772646	0.3281356	0	1
educ	29,228	3.758417	1.542402	0	8
cig	71,813	0.0037737	0.0613148	0	1
sex	71,813	0.548689	0.4976272	0	1
birthwgt	10,954	6115.417	3748.112	500	9998
alc	71,813	0.0363862	0.1872504	0	1
so2cig	71,119	0.0254422	0.6827325	0	30.52

(*Source: Author's own)*

The distribution of some of these variables has been shown in the graphs. The first figure below displays the distribution of responses based on the type of residence (i.e., urban or rural). The second figure shows the distribution of the sex of the infant. As can be seen, there are very few respondents from the urban regions. However, the proportion of male and female infants is almost equal.





Empirical Model

This study uses an empirical model to establish the effect of air quality on infant mortality in India. The present study uses a cross-sectional state-level dataset. The variables' stateso2', 'stateno2' and 'statespm' were the main independent variables, while 'deathage' was the main dependent variable. Further, it also includes a subsample analysis based on the area of residence, i.e., urban or rural. For the empirical model, the OLS regression model has been used to understand the effect of the above-mentioned variables. We chose to include dummy variables in our regression model to make the results easier to understand. We've assumed that zero denotes the lack of a specific event, whereas one denotes the presence of that event. These controls were chosen because they have been used in similar studies.

Results

The results obtained after running the OLS regression are given in Table 3. The tests conducted on our regression model have been summarised in Table 2. On running the Breusch-Pagan / Cook-Weisberg test for heteroskedasticity, a p-value of 0.000 was obtained. Due to the presence of heteroskedasticity, a robust regression (MLR2) was run on the model to control for it. The OLS model used passed the Variance Inflation Factor (VIF) Test for collinearity. The test showed a mean VIF of 1.74 with a maximum VIF of 4.21. Thus, we concluded that our model has little to no collinearity. On running the Ramsey RESET test for omitted variable bias, it was observed to have a p-value of 0.3120. Therefore, the null hypothesis was not rejected, and our chosen regression model did not have any omitted variable bias.

Moreover, our model is linear in parameters – this assumption is satisfied because the relationship between the dependent and independent variables are linear. The data was obtained from a dataset by NFHS and was collected using random sampling. It is also important to point out that regression results after running a robust regression on our initial model did not provide any significant changes, proving that our initial model was suitable regardless of the presence of heteroskedasticity.

Table 3: Regression Tests

ovtest | H_0: *model has no omitted variables* | Omitted Variable Bias Test		
Model	*Prob > F*	*Conclusion*
MLR 1	0.3120	Fail to reject H_0
MLR 2 (*Robust*)	0.3120	Fail to reject H_0
vif | Variance Inflation Factor Test for Collinearity		
Model	*Mean VIF*	*Conclusion*
MLR 1	1.74	No multicollinearity
MLR 2 (*Robust*)	1.74	No multicollinearity
estat hettest | H_0: *Constant variance* | Heteroskedasticity Test		
Model	*Prob > chi2*	*Conclusion*
MLR 1	0.0000	Reject H_0

Note: We don't run this command for MLR 2 as standard errors are robust to heteroskedasticity.

(*Source: Author's own)*

As can be seen from the regression results below (Table 4), overall, the SO2 rate does not significantly affect the age of death of the child. But in the sub-sample analysis of the urban region, the coefficient is significant at the 5% level. A unit increase in the SO2 rate is expected to decrease the life of the infant by one day. The coefficients on SPM rates in all three models are not statistically significant.

The NO2 rate in a state, though, does negatively affect the age of death of an infant. Overall, an increase in the NO2 rate by one is expected to decrease the life of the infant by 0.26 days. In rural regions, an increase in the NO2 rate by one is expected to decrease the life of the infant by 0.31 days. Meaning that the higher the pollution in the air, the younger the infant is at death.

Surprisingly, none of the other variables is significant. Even variables like improved water sources do not seem to affect the age when the infant dies. It is surprising that if it is a male child, he is expected to die around ten days earlier than a girl child, in all three regressions. Similarly, an increase in the birth weight of the child is expected to decrease the number of days an infant lives, though by a marginal amount. However, our R-squared, overall, is pretty low (<0.1).

What is interesting is that, even though the coefficient on 'stateso2' and 'cig' is not significant, the interaction term between the two is significant at the 1% level. This means that if the mother smokes and there is a unit increase in the SO2 rate, the infant is expected to live for ten days less. This is a very unique and important result.

Table 4: Regression Results

	overall	**urban**	**rural**
	b/se	b/se	b/se

stateso2	-0.138	-1.058**	0.125
	0.211	0.387	0.248
stateno2	-.267**	-0.104	-.313**
	0.097	0.200	0.111
statespm	0.008	0.023	0.000
	0.011	0.021	0.013
residence	-2.940	.	.
	2.813	.	.
impwatersource	-2.382	-11.227	-0.716
	3.320	8.373	3.604
educ	-0.100	-0.938	0.222
	0.758	1.463	0.887
cig	31.399	32.203	0.000
	20.160	29.594	.
sex	-10.359***	-12.876*	-9.57***
	2.431	5.002	2.786
birthwgt	-.002***	-.003***	-.002***
	0.000	0.001	0.000
alc	7.554	50.364	2.790
	12.053	50.550	11.938
so2cig	-8.756743**	-13.271	8.352
	2.745	7.553	10.408
_cons	69.708***	89.256***	64.18***
	5.682	12.630	6.415
R-squared	0.013	0.033	0.011
N	5291	1195	4096

*(Source: Author's own; * for p<.05, ** for p<.01, and *** for p<.001)*

Policy Implications & Recommendations

One of the major results from our empirical study is the fact that if a pregnant woman is a smoker, there is a unit increase in the SO2 rate - and the infant is expected to live for up to 10 days less. This result is extremely important for policymakers around the world because it hints at the potentially disastrous effects of cigarettes and smoking for prospective mothers across the globe.

Thus, certain steps must be taken to curb the effects of prenatal smoking. These could include major awareness policies taken by the government in collaboration with tobacco companies. Another particularly effective policy can be combining higher taxes with smoke-free policies that can further act as useful incentives.

From our empirical study, we found NO_2, not SO_2 - to be the most potentially harmful pollutant in the air in India. Nitrogen oxides are a group of extremely reactive, toxic gases. When fuel is burned at high temperatures, several gases are produced. Automobiles, trucks, and various non-road vehicles (such as construction equipment, boats, and so on), as well as industrial sources such as power plants, industrial boilers, cement kilns, and turbines all, create NO_x pollution. NO_x is frequently seen as a brownish gas. It's a powerful oxidiser that plays a key role in the atmospheric reactions that produce ozone (smog) on hot summer days (EPA, 2022)

Thus, it is our recommendation that Indian states adopt regulations that require many aforementioned facilities to reduce NO_x emissions by making process changes (like changes and improvements in the combustion process) or by installing air pollution control equipment to improve the quality of air.

Conclusion

Overall, it is found that the SO_2 rate does not significantly affect the age of death of the child. The NO_2 rate in a state, though, does negatively affect the age of death of an infant. An increase in the NO_2 rate by one is expected to decrease the life of the infant by 0.26 days. In rural regions, an increase in the NO_2 rate by one is expected to decrease the life of the infant by 0.31 days. Meaning that the higher the pollution in the air, the sooner the infant dies. Further, it is also found that if the mother smokes and there is a unit increase in the SO_2 rate, the infant is expected to live for ten days less. This is a very unique and important result.

The enormous burden of mortality and disease caused by air pollution, as well as the significant negative economic effect of lost productivity, might hinder India's goal of becoming a $5 trillion economy by 2024. Reduced air pollution in India through state-specific solutions would have significant advantages for both the population's health and the economy (Pandey et al., 2021). Thus, it is our recommendation that Indian states adopt regulations that require many aforementioned facilities to reduce NO_x emissions by making process changes (like changes and improvements in the combustion process) or by installing air pollution control equipment to improve the quality of air.

Limitations

Like all papers, this study also faces some limitations. Due to data constraints for the air quality data, this paper uses average state-wise SO_2, NO_2, and SPM rates to make generalisations. While this gives us broad results, future research could narrow their focus to region or city-wise analysis and try to collect better air quality data for the same. Also, time constraints and the lack of previous research on this topic, especially in the Indian context, hindered the scope of this research.

References

Bobak, M., & Leon, D. A. (1999). The effect of air pollution on infant mortality appears specific for respiratory causes in the postneonatal period. *Epidemiology (Cambridge, Mass.)*, *10*(6), 666–670.

Buka, I., Koranteng, S., & Osornio-Vargas, A. R. (2006). The effects of air pollution on the health of children. *Paediatrics & child health*, *11*(8), 513–516.

Centers for Disease Control and Prevention. (2021, September 8). *Infant mortality*. Centers for Disease Control and Prevention. Retrieved May 6, 2022, from https://www.cdc.gov/reproductivehealth/maternalinfanthealth/infantmortality.htm

Currie J. (2013). Pollution and Infant Health. *Child development perspectives*, *7*(4), 237–242. https://doi.org/10.1111/cdep.12047

Deshpande, T. (2021, December 15). *India has 9 of world's 10 most-polluted cities, but few air quality monitors*. Indiaspend. Retrieved May 6, 2022, from https://www.indiaspend.com/pollution/india-has-9-of-worlds-10-most-polluted-cities-but-few-air-quality-monitors-792521

Environmental Protection Agency. (n.d.). *Nitrogen Oxides Control Regulations | ground-level ozone | New England | US EPA*. EPA. Retrieved May 4, 2022, from https://www3.epa.gov/region1/airquality/nox.html

Erdoğan, E., Ener, M., & Arıca, F. (2013). The strategic role of infant mortality in the process of economic growth: An application for high income OECD countries. *Procedia - Social and Behavioral Sciences*, *99*, 19–25. https://doi.org/10.1016/j.sbspro.2013.10.467

Government of India Ministry of Health and Family Welfare India. DHS Program. (2017, December). Retrieved May 5, 2022, from https://www.dhsprogram.com/pubs/pdf/FR339/FR339.pdf

Hajat, S., Armstrong, B., Wilkinson, P., Busby, A., & Dolk, H. (2007). Outdoor air pollution and infant mortality: analysis of daily time-series data in 10 English cities. *Journal of epidemiology and community health*, *61*(8), 719–722. https://doi.org/10.1136/jech.2006.053942

Heft-Neal, S., Burney, J., Bendavid, E., & Burke, M. (2018). Robust relationship between air quality and infant mortality in Africa. *Nature*, *559*(7713), 254–258. https://doi.org/10.1038/s41586-018-0263-3

Heft-Neal, Sam & Burney, Jennifer & Bendavid, Eran & Voss, Kara & Burke, Marshall. (2020). Dust pollution from the Sahara and African infant mortality. Nature Sustainability. 3. 1-9. 10.1038/s41893-020-0562-1.

Improved sanitation facilities and drinking-water sources. World Health Organization. (n.d.). Retrieved May 5, 2022, from https://www.who.int/data/nutrition/nlis/info/improved-sanitation-facilities-and-drinking-water-sources

Kenneth Y. Chay, Michael Greenstone, The Impact of Air Pollution on Infant Mortality: Evidence from Geographic Variation in Pollution Shocks Induced by a Recession, *The Quarterly Journal of Economics*, Volume 118, Issue 3, August 2003, Pages 1121–1167, https://doi.org/10.1162/00335530360698513

Pandey, et. al (2021). Health and economic impact of air pollution in the States of India: The global burden of disease study. *The Lancet Planetary Health*, *5*(1). https://doi.org/10.1016/s2542-5196(20)30298-9

World Health Organization. (n.d.). *More than 90% of the world's children Breathe Toxic Air Every Day*. World Health Organization. Retrieved May 6, 2022, from https://www.who.int/news/item/29-10-2018-more-than-90-of-the-worlds-children-breathe-toxic-air-every-day