Clean Air Catalyst

AIR POLLUTION AND REPRODUCTIVE HEALTH - ANNOTATED BIBLIOGRAPHY

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Summary

This annotated bibliography briefly describes review articles on air pollution and reproductive health. Relevant studies were identified through searches in PubMed using keywords ((((AIR POLLUTION[Title/Abstract]) OR (PARTICULATE MATTER[Title/Abstract])) AND ((REPRODUCTIVE HEALTH[Title/Abstract])) OR (MATERNAL HEALTH[Title/Abstract])) OR (FERTILITY[Title/Abstract])). We found 128,773 studies in the initial search. We filtered the studies out by only including studies published in peer-reviewed journals within the last 7 years and excluding non-English studies, duplicates, and those with small sample sizes. At this stage, we left with 2,524 studies. After screening abstracts and titles for relevance, we selected 20 studies to be further examined. We extracted information on study design, sample size, findings, and limitations.

Grouped by health outcomes, the following annotated bibliography was structured alphabetically by author and includes each study's main findings, limitations, and contributions to understanding air pollution's effects on health outcomes. Each source was critically evaluated based on its methodology, scope, and relevance to the research question.

Limitations

Most studies used air quality data from monitoring stations or residential estimations, which may not reflect exactly how much pollution individuals are exposed to. There are also still

relatively few studies focused on non-pregnancy outcomes, and the results for the ones that do exist are more inconsistent, which may be due to methodological issues.

These findings highlight the urgent need for more research and stronger policies to reduce air pollution and protect reproductive and maternal health.

Maternal Health

Lin SY, *et al*. (2021). *Increased Incidence of Dysmenorrhea in Women Exposed to Higher Concentrations of NO, NO_2, NO_x, CO, and $PM_{2.5}$: A Nationwide Population-Based Study.* Front Public Health. 17;9:682341. doi: 10.3389/fpubh.2021.682341. This study investigates the link between air pollution and dysmenorrhea in Taiwanese women. Using a large sample of over 296,000 women, it found that exposure to pollutants such as NO, NO_2, NOx, CO, and $PM_{2.5}$ significantly increased the risk of developing dysmenorrhea. Women exposed to the highest quartiles of these pollutants had hazard ratios ranging from 16.7 to 33.1, with the highest risks in more urbanized areas. A particularly strong association was noted with NOx and $PM_{2.5}$, with women in the highest exposure quartiles 27 times more likely to develop dysmenorrhea. The study also suggested that combined exposure to multiple pollutants further increased the risk. However, the study acknowledges several limitations, such as the lack of detailed information on individual risk factors like family history, smoking, and lifestyle choices, as well as potential underreporting of dysmenorrhea and the use of zip codes for estimating pollutant exposure.

Kim JH, *et al.* (2022). *Effects of Exposure Duration and Exposure Levels of Ambient Air Pollutants on the Risk of Polycystic Ovarian Syndrome: A 2015-2019 Korean Population-Based Cohort Study.* Toxics. 18;10(9):542. doi: 10.3390/toxics10090542.

This study investigates the link between air pollution exposure and the risk of polycystic ovarian syndrome (PCOS) in a Korean population-based cohort from 2015 to 2019. Using real-time air quality data from the Korean Ministry of Environment, the researchers analyzed average monthly concentrations of PM10, PM2.5, O3, CO, SO2, and NO2 from 2014 to 2018. They applied spatial prediction models to estimate individual exposure. Analyzing 237,582 PCOS cases, they found that PCOS incidence rose annually, and prolonged exposure to PM2.5, O3, and NO2 increased PCOS risk by 1.29–1.52 times. The highest NO2 levels correlated with a 1.75-fold increased risk, while SO2 and CO exposure in moderate ranges also elevated risk. The findings suggest a strong association between air pollution and PCOS risk in Korea.

Liang Z, *et al.* (2020). *Association between air pollution and menstrual disorder outpatient visits: A time-series analysis.* Ecotoxicol Environ Saf;192:110283. doi: 10.1016/j.ecoenv.2020.110283. This study explores the relationship between short-term air pollution exposure and menstrual disorder outpatient visits in Xi'an, China, from 2010 to 2016. Using an over-dispersed Poisson generalized additive model, researchers analyzed 51,893 outpatient visits while adjusting for weather and day-of-week effects. They found that a 10 μg/m³ increase in PM10 and NO2 levels led to a 0.236% and 2.173% rise in menstrual disorder visits, respectively, with stronger effects observed in women aged 18–29. No significant link was found with SO2 exposure. This study provides the first evidence of short-term air pollution contributing to menstrual disorders, highlighting the need for further research on air pollution's impact on reproductive health.

Fertility

Carré, J., *et al*. (2017). *Does Air Pollution Play a Role in Infertility? A Systematic Review*. Environmental Health, 16(82). https://doi.org/10.1186/s12940-017-0291-8. This systematic review explores the impact of air pollution on fertility, focusing on both human and animal studies. It examines pollutants such as particulate matter (PM), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and ozone (O_3). The findings show that exposure to $PM_{2.5}$ and NO_2 is linked to reduced fecundability in humans, while SO_2 exposure before conception is associated with lower chances of pregnancy. In animal studies, air pollution negatively affected sperm quality and ovarian function, leading to reduced fertility. Pollutants act by disrupting hormones, inducing oxidative stress, and causing DNA damage. However, most human studies relied on estimated pollution data from air monitoring stations, which may not accurately reflect individual exposure. The review also highlights that traffic-related air pollution increases the risk of miscarriage and other reproductive issues. A major limitation is the reliance on observational and retrospective studies, which introduces bias and limits the ability to establish causality.

Conforti, A., *et al*. (2018). *Air Pollution and Female Fertility: A Systematic Review of Literature*. Reproductive Biology and Endocrinology, 16(117). https://doi.org/10.1186/s12958-018-0433-z. This systematic review examines the impact of air pollution on female fertility, focusing on both natural conception and in vitro fertilization (IVF). The review analyses 11 studies investigating pollutants such as NO_2, SO_2, PM_{10}, $PM_{2.5}$, CO, and O_3. The findings suggest that exposure to NO_2 and O_3 is associated with lower live birth rates in women undergoing IVF. PM_{10} exposure is linked to an increased risk of miscarriage in both natural conception and IVF cases. $PM_{2.5}$ is shown to reduce fecundability in the general population, while SO_2 and CO are linked to higher rates of miscarriage and stillbirths. The review emphasizes that air

pollution may negatively impact female fertility and pregnancy outcomes. However, the studies included in the review were largely observational and retrospective, increasing the risk of bias. Variability in study designs, pollution exposure assessments, and population characteristics made it difficult to compare results across studies. Many studies used air monitoring stations for pollution exposure, which might not accurately reflect individual exposure levels.

Liu, S., *et al*. (2024). *Ambient Ozone and Ovarian Reserve in Chinese Women of Reproductive Age: Identifying Susceptible Exposure Windows*. Journal of Hazardous Materials, 461, Article 132579. https://doi.org/10.1016/j.jhazmat.2023.132579. This study explores the impact of ambient ozone exposure on ovarian reserve in 6008 Chinese women of reproductive age. The researchers used anti-Müllerian hormone (AMH) levels to measure ovarian reserve and evaluated ozone exposure during different time windows, including 2, 4, 6 months, and 1 year before AMH measurement. The study found that higher ozone exposure was significantly associated with decreased AMH levels, especially during long-term exposure and the secondary to small antral follicle stage. AMH levels decreased by up to 8.91% for each 10 μg/m³ increase in ozone over a 1-year period. The effects were most pronounced in younger women, those with higher BMI, and those exposed to higher ambient temperatures. However, the study was limited by the use of residential addresses to estimate ozone exposure, which may lead to some misclassification. Additionally, the participants were recruited from a fertility center, limiting the generalizability to the broader population. The study also did not account for other air pollutants that could impact ovarian reserve.

Shen, Z., *et al*. (2024). Association Between Air Pollution and Male Sexual Function: *A Nationwide Observational Study in China.* Journal of Hazardous Materials, 469, Article 134010. https://doi.org/10.1016/j.jhazmat.2024.134010. This study investigates the association between air pollution and male sexual function in a large-scale, nationwide sample of 5047 men in China. It examines the effects of six air pollutants—$PM_{2.5}$, PM_{10}, SO_2, CO, NO_2, and O_3—on erectile dysfunction and premature ejaculation. The results show that NO_2 exposure has a significant negative impact on erectile function (measured by IIEF-5) during 1, 3, and 6 months of exposure. Additionally, $PM_{2.5}$ exposure over 12 months is linked to an increased risk of premature ejaculation, as shown by higher PEDT scores. The effects of air pollution are more pronounced in men with a normal BMI, extroverted personalities, and those who smoked or consumed alcohol. However, the study has several limitations, including the use of monitoring station data, which might not accurately reflect individual pollution exposure levels. Self-reported sexual function data could also introduce biases such as underreporting or misreporting due to social pressures. The study's findings are specific to the Chinese population, which limits generalization to other populations. Additionally, it did not fully account for other factors like lifestyle or pre-existing health conditions.

Siegel, E. L., *et al.* (2023**).** *Indoor and Outdoor Air Pollution and Couple Fecundability: A Systematic Review.* Human Reproduction Update, 29(1), 45-70. https://doi.org/10.1093/humupd/dmac029. This systematic review examines the impact of indoor and outdoor air pollution on couple fecundability, measured by time to pregnancy (TTP). The study analyses 33 papers, finding that exposure to outdoor pollutants such as $PM_{2.5}$, nitrogen oxides, and traffic-related air pollution (TRAP) is associated with delayed conception. Indoor pollutants, particularly secondhand smoke

(SHS) and formaldehyde, also contributed to reduced fecundability. Occupational exposure to certain inhaled chemicals, like solvents and formaldehyde, shows mixed effects on fertility. The review notes inconsistencies in exposure measurements across studies, with some relying on self-reported data rather than real-time monitoring or biomarkers. Inconsistent exposure windows and lack of personal factors like smoking and lifestyle in many studies were additional limitations. The review emphasises the need for more prospective cohort studies to better assess the relationship between air pollution and fertility.

Wieczorek, K., *et al*. (2024). *Exposure to Air Pollution and Ovarian Reserve Parameters.* Scientific Reports, 14(461). https://doi.org/10.1038/s41598-023-50753-6. This study examines the effect of air pollution on ovarian reserve parameters in 511 women attending a fertility clinic in Poland. The researchers measured antral follicle count (AFC) and hormone levels, including Anti-Müllerian hormone (AMH), follicle-stimulating hormone (FSH), and estradiol (E2), and compared them to levels of ambient air pollutants like $PM_{2.5}$ and SO_2. The results show that higher exposure to $PM_{2.5}$ is significantly associated with lower AMH levels and decreased AFC, indicating a reduction in ovarian reserve. SO_2 exposure also negatively impacts AFC. These effects are more pronounced among women with female factor infertility and those over 35 years of age, suggesting that certain groups may be more vulnerable to air pollution's reproductive effects. The study highlights the potential adverse impact of air pollution on female fertility, particularly in urban environments. Limitations include the use of pollution data based on participants' ZIP codes, which may not capture individual exposure levels accurately. The study was conducted in a fertility clinic, which limits the generalizability of the findings to the general population. Furthermore,

the study did not account for other environmental factors like temperature or indoor pollution that could influence the results.

Zhang, R., *et al.* (2024). *Association between Fine Particulate Matter and Fecundability in Henan, China: A Prospective Cohort Study.* Environment International, 188, Article 108754. https://doi.org/10.1016/j.envint.2024.108754. This study examines the association between fine particulate matter ($PM_{2.5}$) exposure and fecundability among women in Henan, China. It used data from 751,270 women in the National Free Pre-conception Check-up Project, tracking their attempts to conceive. The results show that higher exposure to $PM_{2.5}$ is associated with a 5% decrease in fecundability for every 10 μg/m³ increase in exposure. The negative effect of air pollution is more pronounced among older women, those with higher BMI, and women living in urban areas. The highest quartile of $PM_{2.5}$ exposure demonstrates the largest reduction in fecundability, with lower hazard ratios observed in these women. However, the study relies on county-level pollution data instead of individual exposure levels, which could limit precision. It also did not account for other environmental factors like temperature and humidity, or male fertility factors. Another limitation is the self-reported pregnancy data, which could lead to underreporting of early miscarriages.

Pregnancy

Jia, L., *et al*. (2020). *Association of Ambient Air Pollution with Risk of Preeclampsia During Pregnancy: A Retrospective Cohort Study*. BMC Public Health, 20(1663). https://doi.org/10.1186/s12889-020-09719-w. This study examines the link between air pollution and preeclampsia in pregnant women in Hebei Province, China. It includes 116,042 women and analyses their exposure to pollutants such as $PM_{2.5}$, PM_{10}, NO_2, SO_2, CO, and O_3. The results show that higher levels of $PM_{2.5}$, PM_{10}, NO_2, and O_3

during the first and second trimesters significantly increased the risk of preeclampsia. Additionally, high concentrations of SO_2 and CO are associated with preeclampsia, but only in the second trimester. The study highlights the potential health risks posed by air pollution during pregnancy. Limitations include the use of generalised pollution data rather than individual exposure measurements and the lack of personal risk factor data. It also didn't analyse interactions between different pollutants.

Liu, R., *et al*. (2022). *Association of Ambient Fine Particulate Matter Exposure with Gestational Diabetes Mellitus and Blood Glucose Levels During Pregnancy.* Environmental Research, 214, Article 114008. https://doi.org/10.1016/j.envres.2022.114008. This study examines the impact of ambient $PM_{2.5}$ exposure on the risk of gestational diabetes mellitus (GDM) and blood glucose levels during pregnancy in Beijing, China. It involved 165 pregnant women and estimated $PM_{2.5}$ exposure during three key periods: three months before pregnancy, the first trimester, and the second trimester. The results show that a 10 μg/m³ increase in $PM_{2.5}$ during the first trimester is associated with an 89% higher risk of GDM. Additionally, higher $PM_{2.5}$ exposure during the second trimester is linked to elevated blood glucose levels, with a 17.70% and 15.99% increase in 1-hour and 2-hour glucose levels during oral glucose tolerance tests. The study identifies sensitive exposure windows for GDM and elevated blood glucose between the 21st and 27th weeks of pregnancy. However, the small sample size and reliance on data from two hospitals limit the generalisability of the findings. The use of self-reported indoor air quality and address-based pollution exposure assessments may also introduce misclassification errors. The study did not account for gestational weight gain, which could affect blood glucose regulation. Residual confounding from unmeasured factors such as physical activity and diet could also influence the results.

Sun, M., *et al*. (2020). *The Correlation Between $PM_{2.5}$ Exposure and Hypertensive Disorders in Pregnancy: A Meta-analysis.* Science of the Total Environment, 703, Article 134985. https://doi.org/10.1016/j.scitotenv.2019.134985. This meta-analysis examines the relationship between PM2.5 exposure and hypertensive disorders in pregnancy (HDP), including gestational hypertension and pre-eclampsia. The study analyse data from 10 epidemiological studies involving 788,768 pregnant women. Results show that for every 10 μg/m³ increase in $PM_{2.5}$ exposure, the risk of HDP increased by 52%. A 31% higher risk of pre-eclampsia is also observed for the same increase in $PM_{2.5}$ exposure. However, the study finds no significant association between $PM_{2.5}$ and gestational hypertension. The first and third trimesters are identified as the most vulnerable periods for $PM_{2.5}$ exposure during pregnancy. Limitations include high heterogeneity among studies due to differences in study design, exposure assessment, and outcome definitions. Most studies used data from central air pollution monitoring stations, which may not accurately reflect individual exposure levels. The exclusion of women with pre-existing chronic conditions could have underestimated the overall risk.

Tang, X., *et al*. (2020). *Air Pollution and Gestational Diabetes Mellitus: Evidence from Cohort Studies.* BMJ Open Diabetes Research & Care, 8(e000937). https://doi.org/10.1136/bmjdrc-2019-000937. A systematic review and meta-analysis were performed to explore the relationship between air pollution exposure and gestational diabetes mellitus (GDM). It analyses 13 studies involving over 1.5 million participants. The findings reveal that exposure to nitrogen dioxide (NO_2), nitrogen oxides (NOx), and sulfur dioxide (SO_2) significantly increase the risk of GDM. $PM_{2.5}$ exposure during the second trimester also shows a positive association with GDM, with a 7% increased risk for each 10 μg/m³ increase in $PM_{2.5}$. However, pollutants like

black carbon, carbon monoxide, ozone, and PM_{10} does not demonstrate a significant impact on GDM risk. The study highlights the potential role of air pollution in increasing GDM risk, especially during critical pregnancy periods like the second trimester. Limitations include the observational design of the studies, limiting the ability to establish causality. Exposure assessments based on monitoring station data may not accurately reflect individual exposure. The studies also lack control for other factors like diet, physical activity, and socioeconomic status that may affect GDM risk.

Birth outcomes

Soesanti, F., *et al* (2023). *The Effect of Exposure to Traffic-Related Air Pollutants in Pregnancy on Birth Anthropometry: A Cohort Study in a Heavily Polluted Low-Middle Income Country.* Environmental Health, 22, 22. https://doi.org/10.1186/s12940-023-00973-0. This cohort study examines the effect of traffic-related air pollution exposure during pregnancy on birth outcomes in Jakarta, Indonesia. It focuses on 340 mother-infant pairs and measured pollutants like $PM_{2.5}$, soot, NOx, and NO_2 using land-use regression models. The results show that prenatal exposure to soot and NOx significantly reduces birth length. Soot exposure is linked to a 3.83 mm reduction in birth length, while NOx exposure causes a 2.82 mm reduction. However, no significant associations are found between air pollution exposure and birth weight or the risk of low birth weight (LBW). The study highlights the potential impact of air pollution on fetal growth, particularly in length, but not weight. Limitations include small sample size and potential exposure misclassification due to using residential addresses to estimate pollution exposure. The findings are also limited to this specific low-middle income setting, reducing their generalizability to other populations.

Wang X, *et al*. (2023). *Relationship Between Outdoor Air Pollutant Exposure and Premature Delivery in China - Systematic Review and Meta-Analysis***.** International Journal of Public Health, 68(1606226). https://doi.org/10.3389/ijph.2023.1606226. Analysing 18 studies, the researchers find that exposure to $PM_{2.5}$ during the entire pregnancy and O_3 during the third trimester are associated with an increased risk of preterm birth. For every 10 µg/m³ increase in $PM_{2.5}$ exposure, the risk of preterm birth increased by 4%, while O_3 exposure in the third trimester raises the risk by 1%. Other pollutants such as PM_{10}, SO_2, and NO_2 do not show significant associations with preterm birth. The study also highlights regional differences, with $PM_{2.5}$ exposure in northern cities and PM_{10} in southern cities being more strongly linked to preterm birth. However, significant heterogeneity across the studies and regions reduced the reliability of the findings. Most exposure assessments were based on monitoring station data, lacking personal exposure data. Further research is needed to refine exposure assessments and better identify critical periods of vulnerability during pregnancy.