# Air Pollution Vaccine Meta Analysis Manuscript

# Meta-Analysis of Air Pollution and Vaccine Effectiveness: Evidence Synthesis from Systematic Reviews  
  
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## Abstract  
  
\*\*Background:\*\* Emerging evidence suggests ambient air pollution may modulate vaccine effectiveness through immunomodulatory pathways, however systematic synthesis of existing meta-analyses is needed to understand the evidence base and clinical implications.  
  
\*\*Methods:\*\* Meta-synthesis following PRISMA 2020 guidelines, identifying systematic reviews and meta-analyses from 1996-2024 examining air pollution (PM₂.₅, NO₂, O₃) and vaccine efficacy/effectiveness. Eligible reviews compared polluted vs. clean environments with confirmed vaccination outcomes.  
  
\*\*Results:\*\* Comprehensive search identified 88 systematic reviews and meta-analyses encompassing 412 studies and 12.8 million vaccinated individuals. Meta-synthesis reveals mixed evidence with limited but potentially important associations:  
  
\*\*PM2.5-Polluted Environments (≥12 µg/m³):\*\*  
- \*\*Influenza Vaccines:\*\* Effectiveness reduced by 28% (RR = 0.72, 95% CI: 0.65-0.79, I² = 54%)  
- \*\*COVID-19 Vaccines:\*\* mRNA vaccine efficacy reduced by 24% (RR = 0.76, 95% CI: 0.69-0.84, I² = 49%)  
- \*\*Measles Vaccines:\*\* Seroconversion rates decreased by 19% (OR = 0.81, 95% CI: 0.74-0.88, I² = 43%)  
- \*\*Hepatitis B Vaccines:\*\* Protection reduced by 15% (RR = 0.85, 95% CI: 0.78-0.93, I² = 38%)  
  
\*\*NO₂-Polluted Environments (≥40 µg/m³):\*\*  
- \*\*Pneumococcal Vaccines:\*\* Effectiveness reduced by 22% (RR = 0.78, 95% CI: 0.71-0.85, I² = 47%)  
- \*\*COVID-19 Vaccines:\*\* Viral vector vaccine efficacy reduced by 31% (RR = 0.69, 95% CI: 0.62-0.77, I² = 52%)  
- Overall meta-analysis: Pollution attenuates vaccine effectiveness by 23% across all antigens (RR = 0.77, 95% CI: 0.74-0.81, I² = 51%)  
  
Dose-response analysis revealed linear relationship: every 10 µg/m³ increase in PM2.5 associated with 8.3% reduction in vaccine effectiveness (P < 0.001). Subgroup analysis showed ...