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RESEARCH LETTER

Influence of coal-derived air pollutants on cognitive and neurobehavioural function among children

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Fine particulate matter is one of the leading causes of ambient air pollution that threatens global public health. About seven million premature deaths occur annually in low- and middle-income countries [1]. Among all air pollutants, coal dust arising from coal extraction, storage, and combustion, including fine particles generated during coal mining, contributes to major personal health and occupational complications [2]. Burned coal produces a waste by-product known as coal ash, which is a major component of inhalable particulate matter ranging in diameter from 0.1 μm to > 10 μm [3]. Fly ash consists of concentrated metals (loid), approximately 2–10 times more concentrated than the parent coal, and the concentration of lead in coal fly ash was 35 parts per million (ppm) compared to only 4 ppm in parent coal [4].

Long-term exposure to fine dust particles allows them to enter the lungs via the nasal passages and penetrate the bloodstream, ultimately breaching the blood-brain barrier. These particles diffuse directly into deep brain tissues via synaptic transmission. This process triggers increases in beta-amyloid proteins, their precursor protein-cleaving enzymes, cyclooxygenase, and pro-inflammatory cytokines, ultimately causing disruptive changes in brain networks [5]. Increasing dust concentrations cause atrophy in the frontal, parietal, and occipital lobes and the internal capsule, significantly contribute to brain anomalies, and contribute to serious central nervous system disorders that primarily impair cognitive functions such as memory, thought processes, spatial orientation, language abilities, and social and judgmental capabilities [6]. Coal ash components such as lead, mercury, and arsenic induce severe adverse health outcomes affecting multiple organ systems and disrupt brain development, impairing cognitive function [7]. The objective of the present study was to examine whether children living near coal-fired power plants exhibit lower cognitive and neurobehavioural functioning.

The community-based cross-sectional study was conducted in Cuddalore district, Tamil Nadu, India, between January and March 2026. A total of 190 were screened initially. Sample size estimation was performed using an assumed moderate effect size of 0.5, an alpha level of 0.5 and a statistical power of 80%. Children were recruited based on performance on the Teste do Desempenho Escolar (TDE) spelling and arithmetic subsets [8]. The TDE criterion was used to identify children with possible learning difficulties relevant to neurocognitive assessment. The inclusion criteria included school-aged children between 8 and 12 years, both males and females, residing near a coal-fired power plant for at least 5 years, scoring below the 25th percentile on the TDE arithmetic and spelling subtests, and consent from

Key messages

Exposure to fine particulate matters increases the risk of cognitive impairment. A community based cross-sectional study was conducted on 115 participants aged between 8 to 12 years. The study showed that children living within 10 miles from the coal-fired plants have higher prevalence of cognitive and neurobehavioral changes compared to children living away 40 miles.

Table 1 Comparison of cognitive and neurobehavioural symptoms between children residing near (Group A) and far (Group B) from coal-fired power plants

	Crude mean (standard deviation)			Adjusted[a] mean (standard deviation)		
	Group A (n=61)	Group B (n=54)	*P*	Group A (n=61)	Group B (n=54)	*P*
MMS score	26.8 (2.0)	32.2 (2.9)	<0.001	26.9 (0.3)	32.3 (0.3)	<0.001
CBCL score	65.7 (2.0)	62.4 (3.9)	<0.001	65.8 (0.4)	62.5 (0.4)	<0.001

MMS indicates Mini-Mental State examination for children; CBCL, Child Behaviour Checklist; Group A, those who live within 10 miles and Group B, 40 miles perimeter of the coal mines.

[a]Data were adjusted for the age and sex of the participants.

one parent. The exclusion criteria included a history of congenital impairment/disorders, premature birth, and other neurological disorders. The samples were categorised into two groups based on locality. Those who lived within 10 miles of coal-fired power plants were considered Group A, and those who lived more than 40 miles away were considered Group B. These (10-mile and 40-mile) cut-offs were selected to represent higher and lower environmental exposure zones, based on regional particulate matter (PM10) dispersion patterns reported in previous environmental studies. Autonomy, consent, and child assent were obtained. The participants' ages and sexes were recorded. The children who satisfied the selection criteria were initially evaluated using TDE subsets and later with the Mini-Mental State Examination for Children (MMS) [9] and the Child Behaviour Checklist (CBCL) [10]. The data analyst was blinded.

Of the 190 participants initially screened, 115 met the final eligibility criteria and completed all assessments (Group A = 61; Group B = 54). The remaining participants were excluded due to incomplete assessments, failure to meet eligibility criteria, or withdrawal of consent. Data were analysed using the R programming language. Descriptive statistics were summarised using the mean and standard deviation. A two-sample *t* test was used to compare outcome measures between groups. The coefficient of variation was used to assess the consistency of the data sets. Multiple linear regression was done to adjust the data for age and sex.

The current study focused on analysing cognitive function using the MMS examination, which showed that participants in Group A (26.9 (2.0)) had higher cognitive deficits than those in Group B (32.3 (2.9)) ($P < 0.001$). Greater changes were observed in the neuro-behavioural symptoms of Group A (65.8 (2.1)) compared with Group B (62.4 (3.9)) ($P < 0.001$). It was hypothesised that children residing near coal-fired power plants would be more susceptible to disrupted brain development and cognitive impairment. These findings are consistent with previous international studies reporting associations between particulate matter exposure and adverse neurocognitive outcomes in children.

Several limitations should be acknowledged. Potential confounding variables, such as socioeconomic status, race, school quality, family income, and parental education, were not evaluated. The short duration of PM10 monitoring may not accurately reflect long-term exposure. However, unequal sample sizes represent a slight limitation that could affect statistical power. Future studies involving larger populations, long-term environmental monitoring, and biomarker-based assessments are recommended to improve the accuracy of exposure estimation and cognitive evaluation. As this was a cross-sectional study, causal interpretation cannot be established. The findings of the present study suggest that children living within 10 miles of coal-fired power plants may exhibit poorer cognitive and neurobehavioural outcomes than those living farther away.

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Author contributions

Manuscript drafting and revising it critically: HS. Approval of the final version of the manuscript: HS, SKK, GN, SE. *Guarantor of accuracy and integrity of the work:* GN, SE.

Conflict of interest

We do not have any conflict of interest.

Data availability statement

Data supporting the findings of the study are available from the corresponding author upon reasonable request.

AI disclosure

AI tool was used for grammar correction and language improvement; however, all interpretations, conclusions and final drafting were independently verified by the authors.

Supplementary file

None

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