Historical Development of Lead Pollution Tolerance Index (LPTI) by CPCB

Auto-exhaust Lead Pollution, Vegetation Biomonitoring and Roadside Greenbelt Development (1982–1992)

Consolidated Scientific Review- Dr. S.K.Tyagi, Former Addl. Director, CPCB

Historical research review | Central Pollution Control Board (CPCB), Ministry of Environment, Government of India | Delhi, India

Research period: 1982–1992
Principal research theme: Lead pollution from petrol-driven automobiles, accumulation of lead in roadside vegetation, plant tolerance and selection of suitable roadside plantation species.

Abstract

During the 1980s, automobile exhaust was a major source of atmospheric lead pollution in Indian metropolitan cities because lead compounds were added to petrol to improve its octane rating and antiknock properties. Increasing vehicular density, combined with the use of leaded petrol, raised concerns regarding contamination of ambient air, roadside soil, vegetation and the wider urban ecosystem.

The Central Pollution Control Board (CPCB) undertook a systematic investigation in Delhi during 1982–1987 to assess the impact of automobile-exhaust lead pollution on roadside vegetation and to identify plant species capable of accumulating atmospheric lead without suffering substantial impairment of growth.

The research programme included ambient-air lead monitoring, soil analysis, foliar lead estimation, and assessment of plant growth through leaf area and biomass measurements. These investigations culminated in the development of the Lead Pollution Tolerance Index (LPTI), an integrated index proposed to identify plant species suitable for roadside plantation and lead pollution mitigation.

The pioneering work associated with D. B. Boralkar, S. K. Tyagi, B. Sengupta and other CPCB scientists represents an early Indian effort to integrate environmental monitoring, plant biomonitoring and ecological mitigation into urban air-pollution management.

This review reconstructs the research programme, its methodology, major findings, species-wise performance and scientific significance between 1982 and 1992.

Keywords: Lead pollution; automobile exhaust; CPCB; Lead Pollution Tolerance Index; LPTI; biomonitoring; roadside vegetation; greenbelt; Delhi; lead accumulation; plant tolerance.

1. Background and rationale

1.1 Lead pollution from automobile exhaust

During the 1980s, tetraethyl lead and other organolead compounds were used as petrol additives to increase octane ratings.

During combustion, these compounds produced lead-containing particulate emissions, which were discharged through automobile exhaust systems.

The major environmental pathways included:

1. Direct atmospheric dispersion of lead-containing particles.
2. Deposition of airborne particles on leaves and other plant surfaces.
3. Accumulation of lead in roadside soil.
4. Uptake of lead through plant roots.
5. Transfer through leaf litter and soil biological processes.

Roadside vegetation was therefore considered important for two complementary purposes:

- Biomonitoring: using plant leaves and tissues to assess environmental contamination.
- Mitigation: identifying species capable of retaining or accumulating pollutants while maintaining satisfactory growth.

1.2 Why the CPCB investigation was important

The CPCB programme was scientifically significant because it attempted to move beyond conventional ambient-air monitoring.

It examined the relationship between:

- Traffic density and atmospheric lead.
- Atmospheric lead and roadside soil contamination.
- Soil and foliar lead accumulation.
- Plant lead accumulation and growth response.
- Plant tolerance and suitability for roadside greenbelt development.

The central research question was:

Which plant species can accumulate or retain maximum quantities of lead while maintaining their growth and physiological performance under roadside pollution conditions?

This question formed the scientific basis for developing LPTI.

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2. Historical evolution of the CPCB research programme (1982–1992)

The research developed progressively from the use of plants as indicators of atmospheric lead pollution to an integrated assessment of lead accumulation and plant tolerance.

1. 1982 – Initial biomonitoring during the IX Asian Games

   Plants were used as biological indicators to investigate changes in atmospheric lead concentration in Delhi during the IX Asian Games. The investigation covered seven major traffic intersections and examined lead accumulation in selected plant leaves.

2. 1984–1985 – Initiation of systematic CPCB investigation

   CPCB initiated a more comprehensive investigation into lead contamination of Delhi's roadside ecosystem, including ambient air, soil and vegetation.

3. 1985–1986 – CPCB technical reports

   The research was documented through the CPCB Ecological Impact Assessment Series, including EIAS/1/1985-86 and EIAS/2/1985-86, under the title Impact of Autoexhaust Lead Pollution on Vegetation in U.T. of Delhi.

4. 1985–1987 – Experimental assessment and LPTI development

   Five plant species were exposed at selected traffic intersections and a control nursery. Their lead accumulation and growth performance were evaluated, resulting in the proposed LPTI.

5. 1990 – International conference publication

   The research was presented as Autoexhaust Lead Pollution of Roadside Ecosystem in Delhi (Part II) at the International Conference on Environment Planning and Management, University of Roorkee.

6. 1992 – Journal publication

   The research was further documented in the Journal of Indian Association of Environmental Management, Volume 19, pages 21–27.

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3. The 1982 IX Asian Games study: Plants as indicators of lead pollution

Publication: Increase of Lead Concentration in Ambient Air During the IX Asian Games 1982 as Indicated by the Plants.

- Authors: D. B. Boralkar, U. Mukharjee and S. B. Singh.
- Journal: Indian Journal of Air Pollution Control.
- Volume 7, Issue 2.
- Pages 65–73.
- Year: 1986.

The study was an early application of plant biomonitoring to assess changes in atmospheric lead concentrations associated with vehicular activity.

3.1 Study design

- Seven major traffic intersections along Delhi's Ring Road.
- Leaf samples collected during October, November and December 1982.
- Two indicator plant species:
  - Nerium indicum
  - Eucalyptus rostrata
- Lead analysis using Atomic Absorption Spectrophotometry (AAS).

3.2 Scientific significance

The study demonstrated the potential of plants to provide an integrated indication of atmospheric lead contamination over a period of exposure.

Unlike conventional air monitoring, which measures pollutant concentration over a defined sampling period, plant biomonitoring can provide information on accumulated deposition and exposure.

The study established an important scientific foundation for the subsequent CPCB investigation of roadside vegetation.

4. CPCB technical reports: EIAS/1 and EIAS/2 (1985–1986)

Two CPCB publications are particularly important in reconstructing the programme.

Report	Title	Publication number
First report	Impact of Autoexhaust Lead Pollution on Vegetation in U.T. of Delhi	EIAS/1/1985-86
Second report	Impact of Autoexhaust Lead Pollution on Vegetation in U.T. Delhi	EIAS/2/1985-86

The 1990 conference paper explicitly cites the first report as a source of the earlier baseline investigation.

The second report is independently listed in the Boralkar publication bibliography. However, its complete contents and precise relationship to the first report require examination of the original CPCB copies.

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Document retrieval references:

- Bibliographic listing of CPCB reports EIAS/1 and EIAS/2.
- 1990 paper – reference to CPCB Report EIAS/1/1985-86.

5. Detailed methodology of the 1985–1987 investigation

This is the central scientific component of the review.

5.1 Study locations

Five traffic intersections were selected in Delhi, representing different levels of vehicular activity.

The locations were:

1. Delhi Gate
2. India Gate
3. Red Fort
4. Ashram
5. Azadpur

Control site: National Physical Laboratory (NPL) Nursery, Delhi.

The NPL Nursery served as the reference location against which pollution exposure and plant growth performance at the traffic intersections were compared.

5.2 Ambient-air lead monitoring

Lead concentrations in ambient air were measured at all five traffic intersections and the control location.

The monitoring schedule was:

- Monthly monitoring during 1985.
- Generally, once every two months during 1986 and 1987.
- A total of 15 observations.

The reported monitoring period covered August 1985 to April 1987.

Reported ambient lead concentrations:

Study period	**Lead concentration (ng/m³)**
January 1984–June 1985	185–324
August 1985–April 1987	199–459

These figures represent the reported range across traffic locations, rather than a city-wide mean.

The 1990 paper also documented seasonal differences, with higher concentrations during winter and monsoon periods than during summer.

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5.3 Plant exposure experiment

Plants initially raised under nursery conditions were installed at the five traffic intersections and the NPL control site.

The plants were harvested periodically, generally at three-month intervals, to assess lead accumulation and growth response.

The five experimental species were:

No.	Scientific name	Common name
1	Alstonia scholaris	Saptaparni
2	Eugenia jambolana	Jamun
3	Polyalthia longifolia	Ashok
4	Populus deltoides (reported as Populus deltoida)	Poplar
5	Putranjiva roxburghii (reported as Putranjiva roxburghi)	Putranjiva

The installation and harvest schedule is reproduced below.

Species	Installation	Harvest
Alstonia	February 1986	May and September 1986
Eugenia	February 1986	May and September 1986
Polyalthia	February and September 1986	May, September and December 1986; April 1987
Populus	September 1986	December 1986 and April 1987
Putranjiva	September 1986	December 1986 and April 1987

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5.4 Parameters and analytical methods

Four principal measurements were incorporated into the assessment.

Parameter	Measurement	Analytical approach
Lead in soil	Soil lead concentration	Jackson (1958)
Lead in foliage	Lead concentration in plant leaves	Washing, acid digestion and AAS
Total leaf area	Leaf area per plant (m^2)	Area-meter

Total biomass	Dry biomass per plant (g)	Gravimetric measurement

The plant foliage was washed before acid digestion and analysis. This is important because it distinguishes the reported measurement from an unwashed leaf measurement containing both surface-deposited and tissue-associated lead.

However, washing alone cannot establish the exact proportion of externally deposited versus internally absorbed lead.

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6. Development of the Lead Pollution Tolerance Index (LPTI)

The most important contribution of this programme was the development of an integrated index that considered both pollutant accumulation and plant growth performance.

6.1 Scientific principle

The CPCB investigators recognised that a plant species should not be considered suitable for roadside plantation merely because it accumulates a high concentration of lead.

A desirable species should:

- Accumulate or retain significant quantities of atmospheric lead.
- Tolerate the associated pollution stress.
- Maintain reasonable leaf area.
- Maintain satisfactory biomass production.
- Remain suitable for long-term roadside plantation.

The index therefore combined two pollution-related parameters with two plant-growth parameters.

6.2 Original LPTI equation

The 1990 paper explicitly proposed the following equation:

$$LPTI = \frac{A + B + C + D}{4}$$

Where:

Symbol	Parameter	Definition
A	Increase in plant lead	Percentage increase in lead concentration in plant foliage relative to control

B	Increase in soil lead	Percentage increase in lead concentration in soil relative to control
C	Retention of leaf area	Percentage retention of total leaf area relative to control
D	Retention of biomass	Percentage retention of total plant biomass relative to control

The reference for each parameter was the corresponding plant at NPL Nursery.

6.3 Interpretation of the four components

A – Percentage increase in plant lead

$$A = \frac{Pb_p - Pb_c}{Pb_c} \times 100$$

Where:

- (Pb_p\) = Lead concentration in plant foliage at the polluted site.
- (Pb_c\) = Lead concentration in the corresponding control plant.

B – Percentage increase in soil lead

$$B = \frac{Pb_{sp} - Pb_{sc}}{Pb_{sc}} \times 100$$

Where:

- (Pb{sp}) = Soil lead concentration at the polluted site.
- (Pb{sc}) = Soil lead concentration at the control site.

C – Percentage retention of leaf area

$$C = \frac{LA_p}{LA_c} \times 100$$

Where:

- (LA_p\) = Total leaf area at the polluted site.
- (LA_c\) = Total leaf area at the control site.

D – Percentage retention of biomass

$$D = \frac{BM_p}{BM_c} \times 100$$

Where:

- (BM_p) = Plant biomass at the polluted site.
- (BM_c) = Plant biomass at the control site.

Important methodological clarification: These equations express the percentage-change and percentage-retention definitions implied by the original paper. The original paper gives the four variables and their average but does not provide a separately printed mathematical definition for each component.

6.4 Interpretation

- Higher A indicates greater foliar lead accumulation.
- Higher B indicates greater soil lead accumulation.
- Higher C indicates better retention of leaf area.
- Higher D indicates better retention of biomass.

A higher LPTI was considered indicative of greater suitability for lead accumulation or adsorption while maintaining tolerance.

An important distinction: LPTI is not a simple measure of lead-removal efficiency. It is a composite screening index combining contamination and plant growth response.

7. Experimental results: Lead accumulation in soil and vegetation

7.1 Lead accumulation in roadside soil

The CPCB investigation reported increasing lead concentrations in the experimental pots during September 1986 compared with May 1986 at several locations.

The authors attributed this to:

- Deposition of airborne lead-containing particles.
- Accumulation of lead on the soil surface.
- Decomposition of contaminated leaf litter.
- Subsequent transfer of lead to the soil environment.

Selected observations from the original Table 2 are reproduced below.

Lead concentration in soil, µg/g; May and September 1986.

Location	Alstonia	Eugenia	Polyalthia
Delhi Gate	16 → 28	18 → 21	20 → 26
India Gate	14 → 18	22 → 28	17 → 27
Ashram	20 → 27	22 → 30	15 → 23
Azadpur	21 → 32	26 → 34	21 → 33

NPL Nursery	12 → 16	14 → 19	13 → 19

The results illustrate the general increase in soil lead at the exposed sites. They also demonstrate that soil contamination was not determined by traffic intensity alone.

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7.2 Lead accumulation in plant foliage

The original Table 3 reports lead concentrations in plant foliage in μg/g dry weight.

Selected results:

Location	Alstonia	Eugenia	Polyalthia
Delhi Gate	20 → 29	22 → 35	23 → 36
India Gate	17 → 24	11 → 24	8 → 23
Ashram	26 → 27	30 → 36	26 → 36
Azadpur	16 → 21	23 → 34	18 → 26
NPL Nursery	12 → 14	9 → 13	6 → 10

Values are May 1986 → September 1986; these are selected species and observations from the published table.

The results demonstrate that:

1. Plant lead concentrations at traffic intersections were generally higher than those at the control nursery.
2. Lead accumulation differed between plant species.
3. Lead concentration in plants did not show a simple direct relationship with traffic density.
4. Seasonal and species-specific characteristics influenced the observed accumulation.

The study also included Populus and Putranjiva, whose lead accumulation varied across locations and sampling periods.

7.3 Effect on plant growth

The research examined total leaf area and dry biomass as indicators of the ability of plants to withstand environmental stress.

The investigators generally observed reductions in leaf area and biomass at the polluted sites compared with the NPL Nursery.

However, three species demonstrated comparatively better growth performance:

- Polyalthia longifolia
- Alstonia scholaris
- Eugenia jambolana

This finding was particularly important because it established that pollutant accumulation should be assessed together with plant growth performance.

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8. Species-wise assessment and suitability for roadside plantation

1. Polyalthia longifolia – Ashok

Promising species

- Good overall growth performance.
- Significant lead accumulation in foliage.
- Comparatively good retention of leaf area and biomass.
- Frequently showed high LPTI values in the original Table 5.

Assessment: One of the most promising species in the CPCB investigation.

2. Alstonia scholaris – Saptaparni

Promising species

- Good growth performance relative to the other species.
- Demonstrated foliar lead accumulation.
- Maintained comparatively satisfactory leaf area and biomass.

Assessment: Suitable candidate for roadside plantation under the conditions investigated.

3. Eugenia jambolana – Jamun , Botanical aspects of Syzygium cumini (L.)

Promising species

- Demonstrated significant lead accumulation.
- Good growth performance.
- Some locations recorded relatively high LPTI values.

Assessment: Another promising species for roadside plantation and lead pollution mitigation.

4. Populus deltoides – Poplar

- Lead accumulation was observed.
- Growth performance was generally less favourable than the three leading species.
- LPTI values varied by location.

Assessment: Requires further evaluation under local climatic and roadside conditions.

5. Putranjiva roxburghii – Putranjiva

- Lead accumulation was recorded at the experimental sites.
- Growth performance was relatively less favourable.
- LPTI values were variable.

Assessment: Less promising than Polyalthia, Alstonia and Eugenia in the reported investigation.

Overall finding of the original CPCB investigation: Polyalthia longifolia, Alstonia scholaris and Eugenia jambolana were identified as promising species for roadside plantation and mitigation of automobile-exhaust lead pollution.

8.1 Species-wise LPTI results

The original Table 5 of the 1990 paper is especially valuable because it reports LPTI observations for individual species at Delhi Gate, India Gate, Ashram and Azadpur.

It includes multiple sampling periods for the species, reflecting the different installation and harvest schedules.

9. Contribution of the CPCB research team

The programme was a collaborative scientific investigation involving experimental design, field monitoring, laboratory analysis, data interpretation and technical reporting.

The available publications allow the following contributions to be documented.

9.1 Dr. D. B. Boralkar

Documented role: Principal research and project leadership

The bibliographic record and research publications establish Dr. D. B. Boralkar's association with the lead pollution and vegetation investigation.

His contributions included:

- Planning and coordination of the vegetation impact investigation.
- Development of the scientific framework for plant-based pollution assessment.
- Interpretation of lead accumulation and plant growth observations.
- Development and presentation of the LPTI concept.
- Publication of the CPCB research findings through reports and scientific papers.

He was the lead author of the 1990 conference paper and the principal author listed in the 1986 publication record.

9.2 Dr. S. K. Tyagi

Documented role: CPCB research team member and co-author

Dr. S. K. Tyagi was associated with the CPCB investigation and is specifically acknowledged as a CPCB co-author in the 1990 paper.

His documented contribution to this research programme includes participation in the scientific investigation and its dissemination.

The 1990 paper identifies his institutional affiliation as:

Central Pollution Control Board, Parivesh Bhavan, East Arjun Nagar, Delhi.

The paper is an important primary bibliographic record of his contribution to the investigation of automobile-exhaust lead pollution and roadside vegetation.

9.3 Dr. B. Sengupta

Documented role: Co-author

Dr. B. Sengupta was a co-author of the 1990 conference paper and associated with the CPCB Office.

His participation forms part of the collaborative CPCB research programme.

9.4 Other researchers

The 1986 Asian Games paper is bibliographically attributed to D. B. Boralkar, U. Mukharjee and S. B. Singh. Their contribution belongs to the earlier plant-biomonitoring phase.

The 1990 conference paper also acknowledges cooperation from colleges and institutional support from CPCB.

A complete individual allocation of field sampling, laboratory analysis, data processing and index calculations cannot be established from the published online record alone. These details should be verified from the original CPCB project files before assigning specific responsibilities to individual team members.

9.5 Institutional contribution of CPCB

The most significant institutional contribution was the establishment of an integrated environmental research approach combining:

- Ambient-air quality monitoring.
- Soil pollution assessment.
- Plant biomonitoring.
- Plant growth and tolerance assessment.
- Development of a composite pollution tolerance index.
- Application of scientific findings to roadside plantation planning.

This was an important example of CPCB's early environmental research moving beyond conventional monitoring towards ecosystem-based pollution assessment.

10. Scientific evaluation: Strengths and limitations of the original LPTI

The LPTI concept was innovative for its time. However, from the perspective of present-day environmental science, some methodological limitations deserve attention.

10.1 Scientific strengths

1. Integrated assessment: The index combined environmental contamination with biological response rather than relying solely on pollutant concentrations.
2. Field-based validation: Plants were exposed under actual roadside conditions.
3. Control comparison: NPL Nursery provided a reference for assessing pollution-associated changes.
4. Multiple sampling periods: Seasonal observations improved understanding of temporal variability.
5. Practical applicability: The results were linked to roadside plantation planning.

10.2 Methodological limitations

Issue	Scientific limitation	Suggested improvement
Lead measurement	Total foliar lead does not distinguish surface deposition from internal uptake	Analyse washed and unwashed leaves separately
Soil analysis	Total lead does not indicate bioavailable lead	Include sequential extraction and bioavailable fractions
Growth parameters	Leaf area and biomass alone may not capture physiological stress	Include chlorophyll, photosynthesis and oxidative stress
Atmospheric exposure	Limited sampling frequency	Use continuous or high-frequency particulate lead monitoring
Plant selection	Limited number of species	Evaluate native species and multiple functional groups
Statistical analysis	Limited information on uncertainty and significance in the accessible reproduction	Include replicates, confidence intervals and statistical tests
Index construction	Equal weighting of four parameters	Validate weighting and sensitivity of the index

10.3 An important scientific consideration: Does lead accumulation mean pollution removal?

Not necessarily.

A plant can accumulate lead in its leaves without permanently removing it from the roadside environment. Contaminated leaves may subsequently fall, decompose and transfer lead to the soil.

The CPCB investigators themselves identified this pathway in their discussion of soil contamination.

Therefore, modern roadside greenbelt studies should distinguish:

- Atmospheric particle interception.
- Surface deposition on leaves.
- Internal plant uptake.
- Accumulation in plant tissues.
- Transfer through leaf litter.
- Long-term retention or removal through biomass management.

This distinction is important when evaluating the actual pollution-mitigation efficiency of vegetation.

11. Historical significance and relevance after the phase-out of leaded petrol

India's subsequent transition away from leaded petrol fundamentally changed the source profile of urban environmental lead pollution.

However, the historical CPCB investigation remains relevant for several reasons.

First: Lead contamination can persist in roadside soils and deposited dust even after the original emission source has been eliminated.

Second: Roadside vegetation continues to intercept particulate matter containing metals such as iron, copper, zinc, nickel, chromium, cadmium and lead from various urban sources.

Third: The original LPTI approach provides a useful historical foundation for developing contemporary plant-based pollution tolerance and biomonitoring methods.

Fourth: The original research provides an opportunity to examine whether species selected under the leaded-petrol era remain suitable for present-day urban greenbelt development.

11.1 Suggested contemporary extension of LPTI

A modernised index could include:

Parameter group	Suggested measurements
Pollutant accumulation	Pb, Cd, Cr, Ni, Cu, Zn and Fe in foliage
Surface deposition	Washable and non-washable particulate fractions
Plant physiology	Chlorophyll, ascorbic acid, leaf pH and relative water content
Growth performance	Leaf area, biomass and annual growth
Particulate interception	PM10 and PM2.5 deposition and retention
Ecological suitability	Native status, drought tolerance, canopy density and survival

The original four-parameter LPTI should be preserved as a historical index. Any expanded index should be separately named, validated and tested rather than retrospectively changing the original equation.

12. Recommendations for further research and policy

I would recommend five practical follow-up initiatives.

1. Digitisation of historical CPCB records

Recover and digitise EIAS/1/1985-86 and EIAS/2/1985-86, including the original tables, photographs, analytical results and project correspondence.

2. Historical LPTI validation

Reconstruct the original LPTI values for all five plant species and four traffic intersections using the original Table 5 and the underlying field data.

3. Contemporary comparative investigation

Repeat the experiment using the same five species at selected Delhi-NCR roadside locations, with additional native species.

4. Multi-pollutant greenbelt evaluation

Extend the research from lead to PM2.5, PM10, black carbon, metals and selected gaseous pollutants.

5. Integration into urban planning

Develop a scientifically validated species-selection protocol for urban roads, highways, traffic intersections, industrial areas and other pollution hotspots.

A particularly useful outcome would be a CPCB technical guidance document on Plant Species Selection for Roadside Pollution Mitigation and Biomonitoring.

13. Consolidated bibliography (1982–1992)

The following bibliography distinguishes primary research publications from supporting bibliographic records.

A. Original research publications and reports

1. Boralkar, D.B., Mukharjee, U. and Singh, S.B. (1986). Increase of Lead Concentration in Ambient Air During the IX Asian Games 1982 as Indicated by the Plants. Indian Journal of Air Pollution Control, 7(2), 65–73.
Bibliographic reference to the 1986 paper.

2. Central Pollution Control Board (1985–86). Impact of Autoexhaust Lead Pollution on Vegetation in Union Territory of Delhi. Ecological Impact Assessment Series, Publication No. **EIAS/1/1985-86**. New Delhi.

3. Central Pollution Control Board (1985–86). Impact of Autoexhaust Lead Pollution on Vegetation in U.T. Delhi. Publication No. **EIAS/2/1985-86**. New Delhi.
CPCB report bibliography.

4. Boralkar, D.B., Tyagi, S.K. and Sengupta, B. (1990). Autoexhaust Lead Pollution of Roadside Ecosystem in Delhi (Part II). Proceedings of the International Conference on Environment Planning and Management, University of Roorkee, India, 5–7 April 1990, pp. 204–210.
Original paper – first part; Original paper – conclusion and references; Original paper – results and LPTI Table 5.

5. Boralkar, D.B., Tyagi, S.K. and Singh, S.B. (1992). Autoexhaust Lead Pollution of Roadside Ecosystem in Delhi. Journal of Indian Association of Environmental Management, 19, 21–27.

The 1992 author attribution is supported by a later bibliographic citation; the original journal issue should be consulted to verify the complete author list and title punctuation.Independent bibliographic citation in a 2009 research paper.

B. Supporting methodological references

6. Jackson, M.L. (1958). Soil Chemical Analysis. Prentice Hall of India, New Delhi.

7. Mishra, R. (1968). Ecology Work Book. Oxford and IBM Publishing Co., Calcutta.

8. American Public Health Association (1977). Methods of Air Sampling and Analysis. Edited by M. Katz, Washington, D.C.

9. Smith, W.H. (1976). Lead contamination of the roadside ecosystem. Journal of the Air Pollution Control Association, 26(8), 753–766.

These references are listed in the bibliography of the 1990 conference paper.

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14. Original research documents: priority access

Key historical documents

1990 conference paper – complete online transcription

Includes experimental methods, Tables 1–5, conclusions and references.

Read the paper

Original LPTI results – Table 5

Species-wise LPTI observations at four Delhi traffic intersections.

View Table 5

CPCB report EIAS/1 and EIAS/2

Bibliographic record of the original technical reports.

View CPCB report references

IGNOU library catalogue

Library holding of the CPCB vegetation pollution report.

View library catalogue

15. Overall conclusions

The CPCB investigations conducted between 1982 and 1987, and subsequently published through 1992, represent an important contribution to the development of environmental biomonitoring and pollution-tolerant roadside plantation strategies in India.

The major scientific achievements were:

1. Establishment of plants as biological indicators of automobile-exhaust lead pollution.
2. Demonstration of lead accumulation in roadside vegetation and soil.
3. Evaluation of plant growth performance under different levels of roadside exposure.
4. Development of the Lead Pollution Tolerance Index (LPTI), integrating lead accumulation, soil contamination, leaf-area retention and biomass retention.
5. Identification of Polyalthia longifolia, Alstonia scholaris and Eugenia jambolana as promising roadside plantation species.

The work of D. B. Boralkar, S. K. Tyagi and B. Sengupta, together with the earlier CPCB research team, deserves recognition as a pioneering contribution to applied environmental science and urban pollution management.

The LPTI concept remains scientifically valuable as an early integrated approach to pollution biomonitoring and ecological mitigation, and deserves to be revisited, validated and updated using contemporary analytical and ecological methods.

16. Suggested author and institutional acknowledgement

For a historical review intended for publication or presentation, the following acknowledgement would be appropriate:

> The present review reconstructs the pioneering research undertaken by the Central Pollution Control Board during 1982–1992 on automobile-exhaust lead

pollution, vegetation biomonitoring and roadside ecosystem protection in Delhi. **Special recognition is due to Dr. D. B. Boralkar and the CPCB research team, including Dr. S. K. Tyagi** and other contributing scientists, for their early work in developing the **Lead Pollution Tolerance Index (LPTI) and identifying suitable roadside plantation species.** The review is based on available CPCB technical reports, contemporary research publications and conference proceedings.

Editorial note: This is a literature-based historical review, not a reproduction of the original CPCB project report. The original 1985–86 reports and the 1990 proceedings should be obtained before submitting a definitive historical paper, especially to verify the complete project-team acknowledgements and numerical LPTI table.

The 1990 paper provides direct documentary evidence of Dr. S. K. Tyagi's co-authorship and CPCB affiliation, which is important when documenting the research team's contributions.