Cosmos Multidisciplinary Research E-Journal | Online Available at www.cmrj.in
Recognized International Peer Reviewed Journal | Impact Factor 5.3 | ISSN No. 2456-1665

Characterization and Implication of Roadside Leaf Dust Accumulated during winter in Nagothane (Roha Taluka), Raigad District, Maharashtra, India-A Survey

V. R. Jadhavar
Assist. Professor in Chemistry
K.E.S. Anandibai Pradhan Science College, Nagothane,
Dist. Raigad, 402106 (Maharashtra), India.
vilas_jadhavar1974@rediffmail.com

Introduction:

Roadside leaf dust (RLD), particulate matter and deposited material on the leaf surfaces of urban and roadside vegetation is an important passive sink and bio-monitor of traffic and industry-related air pollution. In subtropical coastal towns with industrial activity like Nagothane (Roha Taluka, Raigad), winter months often show increased particulate concentrations due to meteorological conditions and increased re-suspension. This survey synthesizes published methods for sampling and characterizing leaf dust, summarizes what similar Indian studies report about seasonal patterns and composition, outlines expected pollutants for Nagothane given its industrial/transport context, and provides a detailed, ready-to-run protocol and a set of implications and mitigation recommendations for local stakeholders.

Study area

Nagothane is a census town in Roha Taluka in Raigad district, Maharashtra, located on the Mumbai–Goa highway (NH-66) and hosting industrial activity (petrochemical/processing units). Its elevation is low (~12 m), and it lies in a coastal, tropical monsoon climate where the coolest months are in winter (roughly December–February) conditions that often favour stable nocturnal layers and higher particulate retention near the surface. These local context facts are relevant for interpreting winter leaf dust loads and particle composition.

Why study roadside leaf dust in winter?

1. **Meteorology:** Cooler, calmer conditions and temperature inversions in winter can reduce dispersion and increase near-surface PM concentrations and deposition rates.
2. **Source activity:** Road traffic (heavy vehicles on NH-66) and nearby industrial emissions (manufacturing/divisions reported near Nagothane) are continuous sources whose particulate fingerprints can be trapped on leaves. **Biomonitoring**

utility: Leaves passively accumulate both soluble and insoluble particles, metals and carbonaceous fractions — offering a low-cost method to map spatial gradients. Prior Indian studies show leaf dust increases nearer highways and during drier/cooler seasons.

What components to expect in roadside leaf dust?

Based on Indian roadway/urban dust studies and industrial contexts, typical components include:

- **Mineral dust** (silicates, oxides) — crustal material from resuspended road dust and soil.
- **Metal pollutants** — Fe, Al, Ca, Zn, Pb, Cu, Mn, Ni, Cr (vehicle wear, brake/tire wear, industrial emissions).
- **Carbonaceous material** — soot/black carbon from combustion.
- **Salt/halides** (near coastal areas) and anthropogenic organics (PAHs) where combustion/industry is present.

  These components will vary by distance from road, tree species (leaf morphology/waxiness), and local sources.

Survey of analytical methods:-

<u>Sampling approaches</u>

Leaf selection: Choose common roadside species (broadleaf evergreen/deciduous present locally), sampling the same species across sites to reduce biological variability. Sample fully expanded mature leaves from mid-canopy height at a standard distance from the trunk/roadside.

Spatial design: Transects perpendicular to the road: e.g., 0 m (road edge), 10 m, 30 m, 100 m, and a background site >500 m from major traffic/industrial influence. Replicate ($n \geq 5$ leaves pooled per tree; ≥ 3 trees per site).

Temporal: Focused winter sampling (e.g., mid-December to end-February) with at least two sampling rounds (early/late winter) to capture variability. Include pre-sampling rain-swash history.

Controls: Clean reference leaves (or washed controls) to account for laboratory contamination. Use gloves, rinse tools, store samples in clean paper envelopes or pre-cleaned glass.

Dust extraction & quantification

Gentle washing method: Leaves are washed with measured volume of distilled/deionized water (with a wetting agent if needed) and sonicated or shaken to detach particles. The washate is filtered on pre-weighed filters for gravimetric mass (µg cm^{-2} leaf area).

Direct scraping (alternate): For insoluble crusts, gently scrape and collect into pre-cleaned vials; less quantitative for very fine PM.

Physical characterization

Gravimetry: Mass per leaf area (µg cm^{-2}) simple and essential.

Particle size analysis: Laser diffraction or microscopy image analysis for size distribution (PM10/PM2.5 fractions on leaves).

SEM (Scanning Electron Microscopy): Morphology and particle shape; with EDS for semi-quantitative elemental mapping. SEM-EDS is widely used to infer sources from particle morphology.

Chemical characterization

XRD (X-ray diffraction): Mineralogical identification for crustal components.

ICP-MS / ICP-OES: For multi-element quantification (metals) after digestion (acid digestion protocols: HNO_3/HCl/HF as appropriate). ICP methods give sensitive concentrations (ng–µg L^{-1}) enabling enrichment-factor calculations.

FTIR: To detect organic functional groups and certain carbonates/nitrates.

GC-MS (optional): For organic pollutants like PAHs if combustion contributions are suspected.

Black carbon / EC-OC analysis: If available, to quantify carbonaceous component.

Quality assurance / quality control (QA/QC)

Field blanks, lab blanks, duplicates, certified reference materials (CRMs) for digestion and ICP, spike recoveries, and procedural blanks for SEM sample prep. Document leaf area precisely (leaf area meter or scanned images).

Data treatment and source inference

Enrichment Factor (EF): EF = (X/Ref)leaf / (X/Ref)crust; Ref often Al or Fe. EF > 10 suggests anthropogenic enrichment.

Principal Component Analysis (PCA) / Positive Matrix Factorization (PMF): To identify source signatures (traffic, crustal, industrial, marine).

Spatial gradients and decay with distance: Fit exponential/linear models to dust mass or metal concentration vs distance from road to estimate influence zones.

Comparison to ambient PM measurements (if available): Correlate leaf dust composition with PM10/PM2.5 ambient records (local station or nearest MPCB data) to understand deposition vs airborne concentration relations.

Expected winter-season observations for Nagothane

Based on literature from Indian highways and industrial towns:

Higher leaf dust mass near road edge and a steep decline within 10–30 m.

Enriched metals (Fe, Zn, Pb, Cu) near heavy traffic and industrial zones; possibly elevated Ni/Cr if petrochemical/steel processes nearby.

Larger fraction of coarse particles (road dust resuspension) but with an increased fraction of fine particulates (PM2.5) adhering during stagnant winter nights.

Species differences: Leaves with rough/waxy surfaces accumulate more dust than smooth leaves.

Implications

Plant physiology and local vegetation

Reduced photosynthetic efficiency: Particle deposition blocks stomatal pores and reduces light capture, leading to decreased photosynthesis and altered pigment levels (chlorophyll reductions reported in multiple studies).

Leaf surface damage & altered transpiration: Dust can change leaf energy balance and water relations, potentially stressing urban trees.

Human health and air quality

Indirect indicator of airborne PM load: While leaf dust is a sink, high deposition implies significant airborne particulate emissions — relevant to respiratory and cardiovascular health for residents, commuters, and workers. Metals bound to particles can be bioaccessible. Winter increases inhalation exposure risk.

Urban planning and ecosystem services

Greenbelt design: Selecting species with high particulate capture and placing vegetation barriers at strategic distances can reduce downwind PM exposure.

Road management: Paving, regular sweeping, and water-sprinkling (street washing) can reduce resuspension. Case studies (e.g., Kolkata) show road dust controls significantly reduce PM.

Recommended field protocol

Sampling layout:-Sites: Road edge (0 m), 10 m, 30 m, 100 m along three transects at representative road segments (including a segment near industrial facilities). Add a background >500 m. Replicates: 3 trees per site × 5 leaves per tree (pooled) = 15 leaves pooled per replicate. Minimum 3 replicates per distance.

Timing:-Two winter rounds: early-winter (Dec 15–Jan 5) and late-winter (Feb 1–Feb 28). Avoid sampling within 48 h after heavy rainfall.

Leaf processing:-

1. Measure leaf area (scanner + software or leaf area meter).
2. Wash leaves in 100–200 mL DI water with controlled shaking; collect washate. Alternatively, sonicate for 5 min in lab sonicator.
3. Filter washate through pre-weighed 0.45 µm PTFE filters for gravimetry and further analysis. Store aliquots for ICP (acidify) and for organics (store at 4°C in amber vials).
4. Keep small subsamples for SEM stubs (air-dry, mount on carbon tape).

Analyses:-Gravimetric (mass mg / leaf area cm^2), SEM-EDS (morphology + elemental), ICP-MS/OES (metals), XRD (minerals), FTIR/GC-MS (organics), and particle size distribution.

Data interpretation -actionable thresholds & indicators

High EF (>>10) for Pb, Zn, Cu → anthropogenic/traffic/industrial source.

Pb, Ni, Cr at elevated levels require public-health attention (workforce & school zones).

Mass per leaf area trends: If road-edge mass is >2× background, prioritise mitigation (street sweeping, tree buffer). (Note: exact action thresholds should be calibrated against local MPCB ambient PM data and national guidelines.)

Recommended mitigation & policy actions for Nagothane

1.Immediate: Increase road sweeping frequency on NH-66 stretches near populated zones; manage unpaved shoulders; limit open storage of dusty materials.

2.Medium-term: Install vegetative barriers with species proven to capture particulates (broad, rough leaves, dense hedges) between road and residential areas.

3.Monitoring: Establish seasonal biomonitoring (leaf dust) coupled with at least one ambient PM10/PM2.5 monitoring station for trend validation.

4.Industrial liaison: Work with industrial units in Nagothane for stack/ fugitive emission audits in winter months and implement best-available techniques to reduce particulate emissions.

Gaps in knowledge & recommended research questions

Local source apportionment: What proportions of leaf-bound metals are from traffic vs industry vs crustal sources in Nagothane? (Requires PCA/PMF + receptor modeling.)

Bioavailability: Which fraction of metals on leaf surfaces is bioaccessible and poses risk for inhalation or ingestion (kids playing near roads)?

Temporal dynamics: How quickly do leaves accumulate/deposit particles after road-dust control measures (e.g., water-sprinkling)?

Species selection study: Comparative capture efficiency of local roadside tree species for a recommended greenbelt program.

References:-

1.Nagothane — town profile & location. (Wikipedia). Wikipedia

2.Climatic averages for Nāgothana / weather patterns. Weather Spark

3.Dust Pollution and Plants — case review and studies from Maharashtra (review chapter). ResearchGate

4.Prusty, BAK et al., Dust accumulation and leaf pigment content — seasonal variation studies demonstrating winter increases and physiological impacts. ScienceDirect

5.SEM-EDS and ICP-MS as complementary analytical techniques for PM/biomonitoring: methodological reviews and validation papers. ScienceDirect+1

6.Recent local/Indian studies showing road dust dominance in urban PM and effectiveness of road-level interventions (news/regulatory reports; e.g., Kolkata case for road-dust management). The Times of India+1