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Evaluation of Settled House Dust Sampling Methods for Chemical, Elemental, and Microbial analyses in Homes

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Abstract

The study tried to evaluate and develop practical, robust methods for collection of settled house dust and airborne particulates suitable for multi-constituent chemical, elemental, and microbial analyses across contrasting environments.Multiple settled-dust collection techniques (vacuum cleaner bags, petri dishes, ceiling boards, spectrotabs/pin stubs, frisbee and bucket deposition gauges, and manual sweeping) and airborne sampling approaches (Tenax sorbent tubes — passive and pumped, PM10 impactors, P-TRAK ultrafine counter, ICOM CO monitor, Burkard biological sampler) were trialed in homes in north-eastern Nigeria (Harmattan and dust-storm seasons) and the UK. Analytical endpoints included TD/GC/MS for VOCs/SVOCs, ICP-MS for metals, SEM particle characterization, and culture/identification of airborne microbes. The results indicated that Vacuum-cleaner-bag sampling yielded the largest and most versatile bulk dust sample masses (sufficient for TD/GC/MS, ICP-MS, and SEM) and was judged most practical for field conditions, transport, and multi-analytical workflows. Passive petri-dish and deposition gauges provided useful deposition rates but often yielded insufficient mass for multi-method chemical analysis, especially in short deployments or in homes with coarse contamination (rodent excreta). Spectrotabs/pin stubs were suitable for SEM particle morphology when transport integrity was preserved. Tenax diffusive and pumped sampling captured event-specific VOC/SVOC emissions (e.g., cooking, generator use, Harmattan episodes) and combined monitoring (P-TRAK and ICOM) allowed activity-correlated assessment of ultrafine particles and CO. It was also found that Settled dust serves as a practical surrogate for integrated indoor exposure to semi-volatile and particle-bound contaminants; however, sampling method influences particle size fractions collected and thus exposure interpretation (e.g., vacuum bags may underrepresent ultrafine inhalable fractions). For multi-constituent exposure assessment in resource-limited or remote settings, vacuum-bag collection combined with targeted active/passive airborne sampling and microbial impaction provides an efficient, replicable approach. We recommend standardized protocols that prioritize vacuum-bag collection for bulk chemical and elemental analyses,

supplemented by passive/pumped Tenax sampling and short-duration instrumentation for event-based airborne metrics; careful sample handling and sieving (e.g., 150 μm) facilitate comparable analyses across sites and seasons.

Introduction

Indoor settled dust is an important reservoir for organic contaminants, metals, and biological agents that contribute to aggregate human exposure via inhalation, ingestion (hand-to-mouth), and dermal contact (Morawska & Salthammer, 2006). In semi-arid regions, episodic atmospheric events (e.g., Harmattan, desert dust storms) increase indoor and outdoor dust loading and may modify dust composition and exposure risk (Dimari et al., 2008; Fullerton et al., 2009). Despite widespread use of diverse sampling methods, there is no universally accepted international standard for settled house dust collection that supports multi-constituent laboratory analyses (Santillo et al., 2003; Afshari et al., 2005). This study reports method development and comparative evaluation of practical sampling protocols suitable for combined chemical, elemental, and microbiological characterization across contrasting climatic contexts.

Methods

Study sites and sampling campaigns

Field method development and initial surveys were conducted in five homes in Damaturu, north-eastern Nigeria, during Harmattan and dust-storm seasons and in multiple UK homes for method validation and comparison. Sampling locations within homes included bedrooms, living rooms, and kitchens.

Settled dust collection methods evaluated

Vacuum cleaner bags

Domestic vacuuming (standard domestic units) of carpets and floors; dust removed, sieved through 150 μm, aliquoted for analyses. Sampling durations: 10–15 min per surface type. Vacuum-bag sampling was repeated across households and seasons.

Passive collectors

Pre-weighed petri dishes (raised 1 –1.5 m) and ceiling boards were deployed for multi-week to multi-month periods to collect settled dust gravimetrically.

Deposition gauges

Frisbee-type and improvised bucket gauges mounted at 1.7m for monthly to multi-month deposition collection, followed by rinsing and filtration onto pre-weighed glass-fiber filters.

SpectroTabs/pin stubs

Adhesive carbon tabs were mounted and exposed to collect dust particles for morphological study using SEM.

Airborne and activity-based sampling

Tenax TA sorbent tubes

Diffusive passive tubes were opned and exposed for 2 weeks at 1.5m height and pumped sampling (Q-Tenax) at 200 ml min−1 for 10–20 minutes during defined activities (cooking with kerosene/firewood, generator use, Harmattan/dust events), analyzed by TD/GC/MS.

PM10 Collection

Personal environmental monitor (PEM) impactors with conditioned 37mm filters for gravimetric PM10 sampling (2 L min−1).

Particle and gas monitors

P-TRAK ultrafine counter and ICOM CO monitor logged 15-s interval data over 10-min activity windows.

Collection of Airborne particles for Microbial Analysis (impaction)

Burkard biological sampler with agar plates for viable bacterial/fungal spore counts and species identification.

Laboratory analyses

Various analyses were carried out with the different dust and airborne particles collected (Mohammed & Crump 2013)

i- Organic chemicals: Thermal desorption GC/MS (TD/GC/MS) and solvent extraction GC/MS for VOCs/SVOCs.
ii- Metals: ICP-MS on sieved dust fractions.
iii- Particle morphology: SEM on carbon-tape-mounted samples.
iv- Microbial identification: Culture-based identification from impacted agar plates.
(Mohammed & Crump 2013)

Table 1: Summary of the various sampling methods experimented

S/N	Equipment	Description	Sampling locations	Output
1	P-TRAK Ultrafine particle counter	Logged reading of real time airborne ultrafine particles	Indoor/ Outdoor	Ultrafine particle count
	ICOM CO monitor	Logged reading of Carbon monoxide	Indoor/ Outdoor	CO concentration
2	Personal Environmental Monitor (PEM)	Collection of airborne PM_{10}	Indoor/ Outdoor	Gravimetric analysis
3	Burkard Biological Air Monitor (impacted)	Collection of airborne bacteria/fungi spores	Indoor/ Outdoor	Identification of microbial species
4	SpectroTabs on pin Stubs.	Dust settled on adhesive tapes	Indoor/Outdoor	SEM analysis
5	Tenax TA tubes	Passive sampling of airborne VOCs/SVOCs	Indoor/Outdoor	TD/GC/MS analysis
6	Q-Tenax tubes	Pumped sampling of airborne VOCs/SVOCs	Indoor/Outdoor	TD/GC/MS analysis
7	Petri dishes	Dust settled on petri dishes	Indoor	Gravimetric analysis
8	Vacuum cleaner	Collection of settled floor dust	Indoor/ Outdoor	VOC/SVOC analysis, SEM
9	Frisbee dust deposit gauge.	Collection of deposited dust	Outdoor	Gravimetric analysis

Results and Discussion

Results

Sample mass yield and suitability

Vacuum-bag sampling consistently provided the greatest mass yield (example gross weights per household 28–36 g; sieved 150 μm fractions 14–25g), enabling parallel TD/GC/MS, ICP-MS, and SEM analyses. Petri dishes and deposition gauges produced insufficient mass for comprehensive chemical profiling, particularly in short deployments or where coarse contamination reduced usable fine fraction. Bucket gauges over extended deployment (4–6 months) produced adequate mass for select analyses (Table 2). SpectroTabs yielded SEM-

amenable samples when transport conditions preserved tape integrity.

Table 2: Quantification of Dust collected via various sampling methods

S/N	Equipment	Description	Mass of dust deposit (g m^{-3})	Remark
1	P-TRAK Ultrafine particle counter	Logged reading of real time airborne ultrafine particles	500,000 /cc	Air pariculates counts, not dust deposit
	Ceiling Board		13.76	Average sample recovered
2	Personal Environmental Monitor (PEM)	Collection of airborne PM_{10}	No quantifiable deposit	Deposit on filter paper
3	Burkard Biological Air Monitor	Collection of airborne bacteria/fungi spores	No quantifiable deposit	Deposit on filter paper
4	SpectroTabs on pin Stubs.	Dust settled on adhesive tapes	5.08	Average recovered
5	Tenax TA tubes	Passive sampling of airborne VOCs/SVOCs	No quantifiable deposit	Only for qualitative analysis
6	Q-Tenax tubes	Pumped sampling of airborne VOCs/SVOCs	No quantifiable deposit	Only for qualitative analysis
7	Petri dishes	Dust settled on petri dishes	4.43	For Microbial analysis
8	Vacuum cleaner	Collection of settled floor dust	24.87	150 μm sieved fractions (g)
9	Frisbee dust deposit gauge.	Collection of deposited dust	5.08	For TD/GC/MS
10	Bucket frisbee (improvised)	Collection of deposited dust	9.65	For TD/GC/MS

Airborne event sampling

Tenax passive and pumped sampling captured VOC/SVOC signatures associated with cooking fuels and generator operation; pumped sampling provided improved time-resolved capture of event peaks. Simultaneous P-TRAK and CO logging permitted association of ultrafine particle bursts and CO peaks with combustion activities.

Microbial flora in Burkhard (and impacted) samples

Burkhard sampling (impacted) on petri dishes followed by media culture and identification revealed the presence of fungal spores and increased cultivable counts of Bacteria in all the samples collected. The microbial analysis has also indicated the presence of a host of fungi and bacterial species in settled as well as airborne indoor/outdoor samples. The fungi colonies identified in both the dust and airborne cultures include *Alternaria spp*, *Aurobaridium*, *Aspergillus niger*, *Aspergillus flavus*, *Cladosporium Fusarium*, *Penicillium*, Pink yeast, White yeast and some unidentified white and yellow colonies. The colonies of bacteria identified include large rod and long filamentous gram positive Bacilli, small pink gram negative Cocci, *Staphylococcus aureus* (gram negative).

Discussions

Among the various sampling methods investigated, collection of dust by vacuum cleaner was deemed the most suitable because a substantial quantity of the sample was obtained in the vacuum cleaner bags which could be used for several chemical analyses whereas, with other methods only small quantities were collected.

Vacuum-bag collection is an operationally efficient method for multi-endpoint dust analysis in both temperate and semi-arid field conditions, aligning with prior multi-country studies that adopt vacuum-collected dust for chemical exposure assessment (Bornehag et al., 2005; Mercier et al., 2011). Nevertheless, vacuum methods may bias against the finest inhalable and ultrafine particle fractions which are relevant for immediate inhalation exposure assessment (Morawska & Salthammer, 2006). Thus, combining bulk settled-dust collection (vacuum bags) with event-based airborne sampling (Tenax tubes, P-TRAK, PM10 impactors) provides a comprehensive exposure characterization strategy suitable for epidemiological interpretation and chemical risk screening (Oomen et al., 2008; Rudel et al., 2010). In semi-arid regions with episodic high deposition (Harmattan/dust storms), extended-duration deposition gauges (bucket-type) can augment vacuum sampling by capturing outdoor-sourced particulates and metals mobilized during events (Dimari et al., 2008).

The airborne samples were mainly collected in order to ascertain the presence of various air pollutants in the indoor/outdoor environments

Researchers have reported to have used different vacuum cleaners for settled dust sampling (Ali et al., 2012; Mercier et al., 2011) and have commented that it gives a better representation of the household dust. In this study collection of settled dust samples from vacuum cleaner bags was also found to be better and is recommended for use to get the practicality and the quantity enough to carry out different types of analysis. Whereas some of the methods are not recommended because very little or insignificant samples were collected after long time of sampling (2 to 4 months).

The dust particles were found to contain mixtures of particles of different shapes and sizes and which may have originated from different indoor and outdoor sources. The strong winds that blow from outside the buildings during the dusty events may be the cause of high presence of sand fractions in the Nigerian dusts. The abundance of bacteria in both dust and air has been reported (Pakarinen et al., 2008; Su et al., 2001). Most of the fungi species identified have been reported in the literature as commonly isolated from plant debris, soil, wood, textiles, and indoor air (Sterflinger et al., 2012).

Practical recommendations

There is need to standardize the vacuum sampling duration, nozzle type, and sieving (e.g., 150 μm) to improve cross-study comparability. Use Tenax passive tubes for integrated VOC/SVOC exposure and pumped Tenax for short-term activity peaks is desirable.

The spectrotab and passive collectors need to be preserved during transport (humidity control) to retain SEM-amenable samples.

Complementing settled-dust sampling with short-duration P-TRAK and CO logging is recommended during representative activities to capture inhalation-relevant exposures.

Conclusions

A combined sampling protocol that prioritizes vacuum-bag collection for bulk chemical and elemental assays, supplemented by passive/pumped Tenax sampling and short-term particle/gas monitoring, offers a pragmatic, field-robust approach for multi-constituent indoor exposure assessment across diverse climatic contexts. Adoption of harmonized procedures (sampling durations, sieving, and storage) will enhance comparability, facilitate risk screening, and support epidemiological linkage to health outcomes.

Conflicts of interest

The authors declare no conflicts of interest.

Ethical Clearance

The samples collected were completed coded during the study for privacy.

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Author contributions

Fatima S. Mohammed, Phd: Conception of idea, research design, collection of dust samples, and supervision of laboratory practicals, supervision of sampling.

Muhammad Lawan Kamaluddeen, Phd: Literature review, design and data analyses.

Abdussamad Yunusa: Coordination/sample collection in Nigeria homes, Laboratory analysis

Derrick Crump, Phd: Mentorship, supervistion and review of practicals/write ups

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