Time to Rethink Dusts

David A. Stoney and Paul L. Stoney

Stoney Forensic, Inc.
14101-G Willard Road, Chantilly, VA 20151
Traditional Focus of Forensic Particle Trace Evidence

• Comparative analysis in individual cases

• Target particle types (fibers, glass, paint… )
  (as opposed to all that are present)
Traditional Focus of Forensic Particle Trace Evidence

• Comparative analysis in individual cases

• Target particle types (fibers, glass, paint . . . ) (as opposed to all that are present)

Good, necessary and appropriate
Traditional Focus of Forensic Particle Trace Evidence

• Comparative analysis in individual cases

• Target particle types (fibers, glass, paint… ) (as opposed to all that are present)

Good, necessary and appropriate,

… but it has limited our perspective
Motivations to Rethink
Motivations to Rethink

Fundamental limitations on probative value of trace evidence
Motivations to Rethink

Fundamental limitations on probative value of trace evidence

• Traces from mass-produced, manufactured materials
Motivations to Rethink

Fundamental limitations on probative value of trace evidence

• Traces from mass-produced, manufactured materials
• Limitations to class associations
Motivations to Rethink

Fundamental limitations on probative value of trace evidence

• Traces from mass-produced, manufactured materials
• Limitations to class associations
• Strength of association?
  - database
  - standard method
  - what’s the relevant population?
  - our focus is on rare events (outliers)
The smaller the frequency, the larger the population we need to estimate it.

Our population is small, with uncertain, heterogeneous composition.

We cannot test or reliably predict frequencies of these rare events.
Individuality Uncertainty Principle in Forensic Science

Our *provable* probabilities will be much, much more common than either our good science or common sense would allow.

Conundrum:

decreasing reliability of frequency estimates with increasing evidential value
More Motivations to Rethink
More Motivations to Rethink
Changes in forensic science practice
More Motivations to Rethink
Changes in forensic science practice
• Technical progress
More Motivations to Rethink

Changes in forensic science practice

• Technical progress
  – Computer-assisted analytical methods
More Motivations to Rethink

Changes in forensic science practice

• Technical progress
  – Computer-assisted analytical methods
  – Data processing capabilities
More Motivations to Rethink

Changes in forensic science practice

• Technical progress
  – Computer-assisted analytical methods
  – Data processing capabilities

More Motivations to Rethink

Changes in forensic science practice

• Professional changes
  - Standardization of methods, routine analyses
  - Increased specialization
  - Reduction of subjective elements
  - Accreditations and certifications
  - Pressure to get more "scientific" or more like other sciences & professions
More Motivations to Rethink

Changes in forensic science practice

• Professional changes
  – Standardization of methods, routine analyses
  – Increased specialization
  – Reduction of subjective elements
  – Accreditations and certifications
  – Get more "scientific" or more like other sciences & professions

• Greater community interest
  – scientists, legal community, public
Clues to Guide a New Approach

With respect to interpretations

- limitation of class association
- case-specific systematic variations that cannot be controlled
- individuality uncertainty principle
Clues to Guide a New Approach

With respect to interpretations

- limitation of class association
- case-specific systematic variations that cannot be controlled
- individuality uncertainty principle
- compellingly strong evidential value for
  - cases with multiple-transfer evidence
  - cases with many-layered paints
Clues to Guide a New Approach

With respect to soil analysis

- issues and approaches addressing combinations of small particles
- arising from a mixture of stochastic and deterministic processes
Clues to Guide a New Approach

With respect to DNA analysis

accepted theory and methodology for calculation of joint probabilities
Clues to Guide a New Approach

With respect to DNA analysis

accepted theory and methodology for calculation of joint probabilities

for a set of modestly rare occurrences
Clues to Guide a New Approach

With respect to DNA analysis

accepted theory and methodology for calculation of joint probabilities

for a set of *modestly rare* occurrences

where reliable bounds can be set on both individual frequencies and correlations
Clues to Guide a New Approach

Multiple transfers of a set of *moderately rare* particles can:

- break the barrier of “class association”
- address the “individuality uncertainty principle” conundrum as we can measure their frequencies and correlations
Clues to Guide a New Approach

Multiple transfers of a set of *moderately rare* particles can:

- break the barrier of “class association”
- address the “individuality uncertainty principle” conundrum as we can measure their frequencies and correlations
Multiple transfers of a set of *moderately rare* particles can:

- break the barrier of “class association”
- address the “individuality uncertainty principle” conundrum

Where do we get sets of particles?
Multiple transfers of a set of *moderately rare* particles can:

- break the barrier of “class association”
- address the “individuality uncertainty principle” conundrum

Where do we get sets of particles?

The reality is: they are always there.
Very Small Particles are Everywhere

We know “VSP” are there
Very Small Particles are Everywhere

We know “VSP” are there, but we don’t usually use them
Very Small Particles are Everywhere

We know “VSP” are there, but we don’t usually use them

• We’re mostly focused on larger, conventional traces
Very Small Particles are Everywhere

We know “VSP” are there, but we don’t usually use them

- We’re mostly focused on larger, conventional traces
  - Exception: GSR particles
Very Small Particles are Everywhere

We know “VSP” are there,
but we don’t usually use them

- We’re mostly focused on larger, conventional traces
  - Exception: GSR particles
  - Exception: DNA
The Potential
The Potential

Use fine “piggy-back” particles, on the surface of traditional trace evidence, to test for common source.
The Potential

Use fine “piggy-back” particles, on the surface of traditional trace evidence, to test for common source. Every case becomes a multiple-transfer case.
The Potential

There is extensive air monitoring and environmental health experience in this area

- Study of respirable or near respirable dusts
- Frequencies of occurrence and local monitoring
- Tracing of airborne pollutants to their source
- Automated analysis methods
The Potential

There is extensive air monitoring and environmental health experience in this area

- Study of respirable or near respirable dusts
- Frequencies of occurrence and local monitoring
- Tracing of airborne pollutants to their source
- Automated analysis methods

There is also forensic experience in this area

- GSR
The Potential

It is of revolutionary significance that, when working with complex particle mixtures, co-occurring particles can be used to

• independently and quantitatively test alternative attribution hypotheses

• achieve high levels of individuality that cannot be reached through single-particle frequency estimates
Fundamentally Different Approach

It differs from:

– looking for a specific target particle based on the case context

– monitoring for specific particle types environmental hazards, pollutants, security threats

– tracing the source of pollutants

– determining what is happening at a given site
Particle Combination Analysis (PCA)

Use of co-occurring particles to independently and quantitatively test alternative attribution hypotheses
Testing the Approach: Carpet Fibers

Long-term exposures in one place
Very large exposed surface area
Designed to trap small particles
Indoor environments highly variable
Testing the Approach: Carpet Fibers

Method to recover fine particles

Unwashed

Washed
Method to Recover Fine Particles

• Clean bench, filtered reagent 95% ethanol
• 0.5mL ethanol + fiber in 1.5 mL micro-centrifuge tube
• Sonication for 10 minutes, fiber removal
• Vacuum filtration using a 0.4\(\mu\)m polycarbonate membrane filter cut to a 5 mm x 5 mm square
• Filter to carbon tape, carbon coating
• Blank process / solvent control
Recovered Particles Ready for Computer-controlled SEM

Blank

Sample
Example CCSEM Data

client number = W10 part# = 15 psem class = Ca/S project number = LS-11-0021

client number = A1 part# = 1 psem class = Si-rich project number = LS-11-0021
Research Currently Underway

Within and between item variability

- Sets of 10 fibers (reference carpet)
- Individual fibers (“transferred fiber”)
- Nylon household carpets
- Nylon automobile carpets
Research Currently Underway

Within and between item variability

- Sets of 10 fibers (reference carpet)
- Individual fibers (“transferred fiber”)
- Nylon household carpets
- Nylon automobile carpets

To be tested: how likely is a measured particle profile to have originated as a randomly selected profile from the reference population

(multinomial distribution with maximum-likelihood estimation and chi-square)
Stay Tuned

Special Thanks to:
NIJ
Andy Bowen
David Exline

This project was supported in part by Award No. 2010-DN-BX-K244 awarded by the National Institute of Justice, Office of Justice Programs, U.S. Department of Justice. The opinions, findings, and conclusions or recommendations expressed in this presentation are those of the author and do not necessarily reflect those of the Department of Justice.
Time to Rethink Dusts

David A. Stoney and Paul L. Stoney
Stoney Forensic, Inc.
14101-G Willard Road, Chantilly, VA 20151

david@stoneyforensic.com

(References follow)
Class Limitations on Conventional Trace Evidence Interpretations


Coons, RD "Use of Statistics in Evaluation of Trace Evidence,” Trace Evidence Symposium, Clearwater Beach, FL, August 15, 2007

National Research Council, Strengthening Forensic Science in the United States: A Path Forward, National Academies Press, Washington, D.C., 2009, 161-163,167-170; at page 163, "...there have been no studies to inform judgments about whether environmentally related changes discerned in particular fibers are distinctive enough to reliably individualize their source... ". 
Use of Computer Controlled SEM/EDX for Environmental Monitoring


Very Small Particle Data Are Already Being Collected


Velasco P, Characterization of Ambient PM10 and PM2.5 in California, California Environmental Protection Agency Air Resources Board. Sacramento, CA, 2005.

Very Small Particle Data Are Already Being Collected (continued)

Particulate Matter (PM2.5) Speciation Guidance (Final Draft); U.S. Environmental Protection Agency: Research Triangle Park, NC, 1999.


Very Small Particle Data Are Already Being Collected (continued)


Source Attribution of Fine Dusts (Examples)


Highly Variable Local Indoor Environment


