United States Environmental Protection Agency

AMERICAN HEALTHY HOMES SURVEY: A NATIONAL STUDY OF RESIDENTIAL PESTICIDES MEASURED FROM FLOOR WIPES

Daniel Stout , Karen Bradham, Carry Croghan, Peter Egeghy, Paul Jones†, Peter Ashley‡, Eugene Pinzer‡, Warren Friedman, Marielle C. Brinkman, Marcia G. Nishioka, David Cox

Office of Research and Development
NERL, HEASD,EMAB.

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OVERVIEW OF AHHS

Environmental Protection Agency's (EPA) National Exposure Research Laboratory (NERL) and the U.S. Department of Housing and Urban Development's (HUD) Office of Healthy Homes and Lead Hazard Control conducted a national survey of housing related hazards in US residences from May 2005 to March 2006.

EPA/HUD Collaboration was designed to:

- Produce a nationally representative database to provide environmental concentrations of lead, allergens, mold, **pesticides**, and arsenic in and around US residences.
- Assess selected residential concentrations and housing characteristics for the general population.
- Produce first ever national estimates of levels of additional housing related hazards besides lead and allergens.
- Develop distributions of residential concentrations.
- Produce a high quality database for examining changes in the occurrence and magnitude of these environmental concentrations over time.

AHHS OBJECTIVES

Results will address multiple EPA and HUD research objectives, such as:

- improving our understanding of current environmental concentrations of selected chemicals and allergens in US residences
- the key factors influencing these concentrations (housing factors)

The data will be used to:

- monitor changes in levels of health hazards in homes over time where baseline data are available
- refine our understanding of certain patterns identified in the HUD's National Survey of Lead and Allergens in Housing (NSLAH) of 1999-2001
- Produce national estimates of the levels of additional housing related hazards including:
  - specific molds in house dusts.
  - concentrations of residential use **pesticides**.
  - arsenic concentrations in indoor house dusts and soils.
  - relate environmental data to resident questionnaires, which includes specific housing and occupancy characteristics.

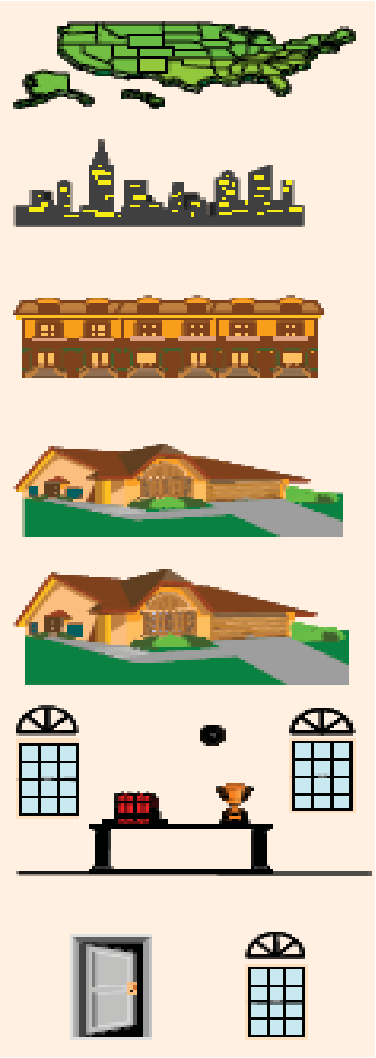
AHHS STUDY DESIGN

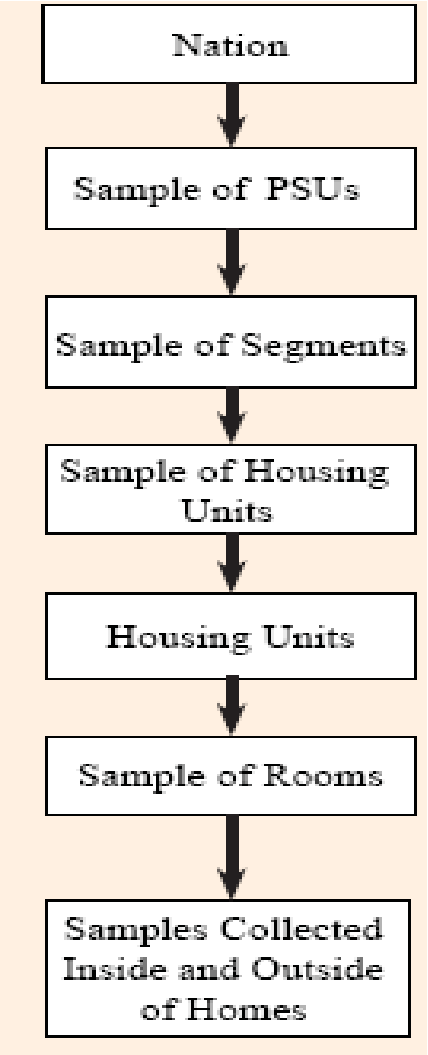
- Data collected from participants in private & public residences (N=1131 homes)

- Nationally representative data reflective of real-world environmental contaminants commonly found in and around the nation's residences

- Sample collection included surface wipe samples from a common living area, homeowner vacuum bags, and soil samples from outside of the home

- Samples and survey information were collected during a single day





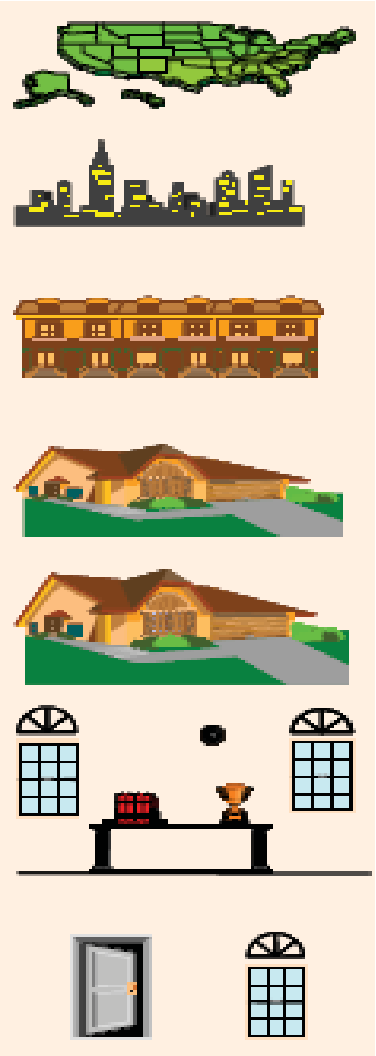
AHHS STUDY DESIGN

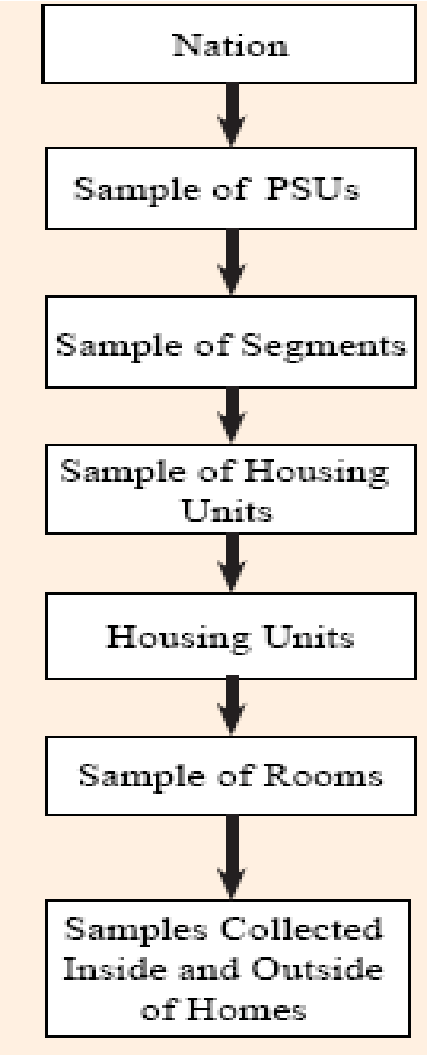
- Nationally representative sample from 1131 housing units (HUs) across the U.S.

- HUs were selected as a 3-stage cluster sample.

1. Selection of 100 PSUs, most of which were MSAs.
2. Five census blocks selected at each PSU.
3. Selection of 4 to 6 HUs acquired from a commercial list.

- A subset of 500 HUs were randomly selected for pesticide sampling.





AHHS HARD SURFACE SAMPLING PROCEDURES FOR PESTICIDES

- Randomly selected sub-sample of 500 homes.

- Surface wipe procedures were used to collect pesticide residues from hard floor surfaces.

- Criteria for surface selection:
  - -hard surface (no carpeting)
  - -not in primary walk way
  - -typically kitchen areas
  - -not damaged by wetting agent (IPA)
  - -accessible

AHHS HARD SURFACE SAMPLING PROCEDURES FOR PESTICIDES

Sample collection kits consisted of :

-Nitrile gloves

-two, 10-mL vials of IPA (wetting agent)

-two, 4 in X 4 in surgical gauze sponges (solvent extracted in Hexane and DCM)

-aluminum template (929 cm^2 X 2 = 1858 cm^2)

Target Compounds Analyzed by Multi-Residue Extraction and Analysis Method for Surface Wipes

Organochlorines

π-Chlordane
π-Chlordane
Heptachlor
p,p'-DDT
p,p'-DDE

Organophosphates

Chlorpyrifos
Diazinon
Malathion

Neonicotinoid

Fipronil

Synergist

Piperonyl Butoxide

Pyrethrins/ Pyrethroids

Allethrin
Bifenthrin
Cyfluthrin
λ-Cyhalothrin
Cypermethrin
Deltamethrin
Esfenvalerate
Fenpropathrin
Imiprothrin
cis-Permethrin
trans-Permethrin
Prallethrin
Pyrethrins
Resmethrin
Sumithrin
Tetramethrin

CHEMICAL ANALYSIS

- Add Surrogate Recovery Standard (SRS).
- Extract in 33-mL ASE vessel with Dichloromethane (DCM) at 2000 psi and 100 °C.
- Reduce to 1-mL and solvent exchange to hexane.
- Condition 0.5 g aminopropyl SPE with 6-mL DCM
- Elute with two, 6-mL washing of DCM.
- Reduce and bring up to 1-mL.
- Add IS
- Analyze by GC/MS:
  - Column: Phenomenex ZB-35 (silica) capillary column; 30 m X 0.25 mm X 0.25 µm film thickness.
  - Carrier Gas: Helium.
  - Carrier Flow Rate: 1.0 ml/min
  - Injection volume: 2 µL.
  - Injection Mode: Splitless at 300 °C.
  - Temperature Program: 100 °C (1 min); 100-130 °C at 25 °C/min; 130-340 at 6 °C/min; hold at 340 °C for 5 min.
  - MID; 2 ions/ compound.

Mapping of SRS's to Pesticide Analytes

$^{13}C_{12}$-p,p'-DDT	$^{13}C_{10}$-*trans*-chlordane	Fenchlorphos	$^{13}C_{6}$-*trans*-permethrin
p,p'-DDT	–Chlordane	Chlorpyrifos	Allethrin
	–Chlordane	Diazinon	Bifenthrin
	Heptachlor	Malathion	Cyfluthrin
	p,p'-DDE	Piperonyl Butoxide	λ-Cyhalothrin
			Cypermethrin
			Deltamethrin
			Esfenvalerate
			Fenpropathrin
			Imiprothrin
			cis-Permethrin
			trans-Permethrin
			Prallethrin
			Pyrethrins
			Resmethrin
			Sumithrin
			Tetramethrin

PRELIMINARY RESULTS: PYRETHROIDS

Pyrethroid	Frequency of Detection (%)	95th percentile (ng/cm^2)
cis-Permethrin	89	6.7
trans-Permethrin	88	10.1
Piperonyl Butoxide	52	5.0
Cypermethrin (total)	46	13.7
Bifenthrin	33	0.12
Deltamethrin	27	1.0
Cyhalothrin	21	0.18
Sumithrin	21	0.36
Cyfluthrin (total)	17	0.50
Esfenvalerate	15	0.43
Tetramethrin (total)	15	0.18
Allethrin	7	0.14
Fenoproprathrin	4	<MDL
Imiprothrin	3	<MDL
Pyrethrins (I and II)	5 (2)	<MDL
Prallethrin	1	<MDL
Resmethrin	0.5	<MDL

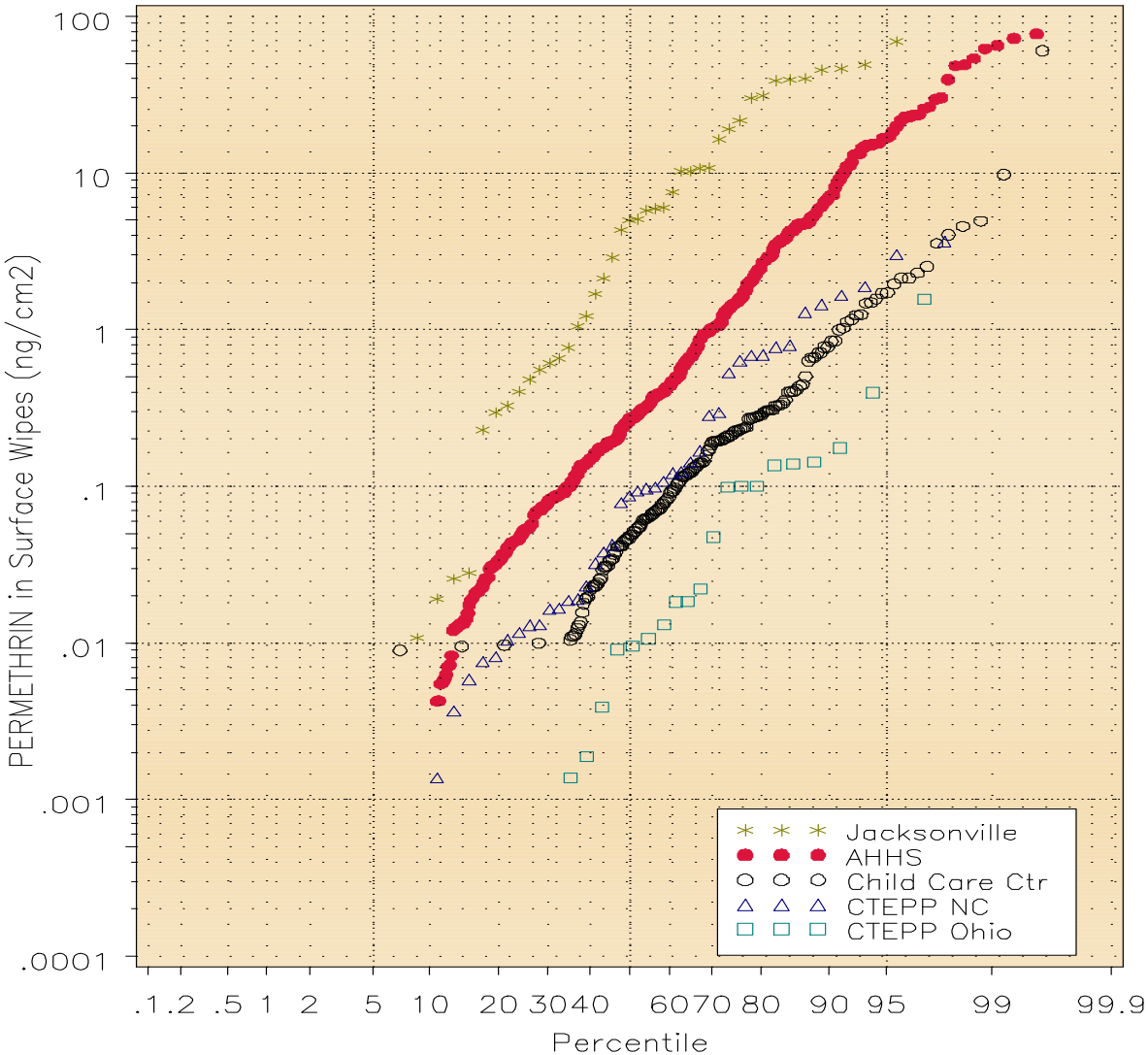
PRELIMINARY RESULTS: ORGANOCHLORINES

Class/Insecticide		
Organochlorine	**Detection Frequency (%)**	**95th percentile (ng/cm^2)**
γ-Chlordane	69	0.37
γ−Chlordane	74	0.57
p,p'-DDT	41	0.11
p,p'-DDE	33	0.04
Heptachlor	13	0.06

PRELIMINARY RESULTS: ORGANOPHOSPHATES AND NEONICOTINOIDS (PHENYL PYRAZOLES)

Class/Insecticide		
Organophosphate	**Detection Frequency (%)**	**95th percentile (ng/cm^2)**
Chlorpyrifos	78	0.67
Diazinon	35	0.15
Malathion	15	0.04
Neonicotinoid	**Detection Frequency (%)**	**95th percentile (ng/cm^2)**
Fipronil	40	0.40

Comparative Plot of the Distribution of Total Permethrin from Several Studies



Tulve et al. 2008

Stout II, D. M.; Bradham, K. M.; Brinkman M. C.; Cox, D.; Egeghy, P. P.; Jones, P. A.; Nishioka, M. G.; Croghan, C. W.; Friedman, W; Pinzer, E. American Healthy Home Survey: A National Study of Residential Pesticides Measured From Floor Wipes. *Environ Sci Technol* (to be submitted for publication).

Tulve NS, Jones PA, Nishioka M, Fortmann RC, Croghan CW, Zhou JY, Fraser A, Cave C, Friedman W. (2006). Pesticide Measurements from the First National Environmental Health Survey of Child Care Centers Using a Multi-Residue GC/MS Analysis Method. Environ Sci Technol 40(20):6269-74.

Morgan MK, Sheldon LS, Croghan CW, Chuang JW, Lordo RA, Wilson NK, Lyu C, Brinkman M, Morse N, Chou YL, Hamilton C, Finegold JK, Hand K, Gordon SM. (2004) "A Pilot Study of Children's Total Exposure to Persistent Pesticides and Other Persistent Organic Pollutants (CTEPP)." EPA/600/R-041/193.

IMPACTS AND USES: PESTICIDES

-Descriptive statistics

-Model inputs for aggregate and cumulative risks

-Comprehensive survey of residential use pyrethroids

-National sample provides bench mark for future surveys

-Regional breakdown can provide temporal comparisons to previous studies

-Co-occurrence of pesticides and their relative concentrations (models)

-Pesticide results and methodology will shape methodology and analyte selection for future studies

ACKNOWLEDGMENTS
We would also like to thank QUANTECH and the many field technicians who helped implement the study.

PLANNED PRODUCTS AND USES

- Abundance of data and information will result, including but not limited to manuscripts/reports on:

  - Overall study design and sampling methodology
  - Lead results and methodology
  - Allergen results and methodology
  - Mold results and methodology
  - Pesticide results and methodology

- Study results used by HUD, EPA, and others to:
  - Identify potential problems in approach and methodology
  - Examine environmental concentrations and their changes over time
  - Develop and implement improved mitigation/risk reduction strategies
  - Reduce future health risks from environmental hazards

AMERICAN HEALTHY HOMES SURVEY

Results for
Lead and Arsenic

David Cox
QuanTech

AHHS DESIGN

- Follow-on to NSLAH (1998-1999)
- Permanently-occupied homes where children may live
- Three-stage sample

  -100 PSUs (proportional to population)

  -4-12 “segments” per PSU

  -4 or 5 homes per segment

AHHS DESIGN (cont.)

- Two-person team per PSU (Interviewer and Certified Risk Assessor)

  -Recruit homes

  -Interview occupant

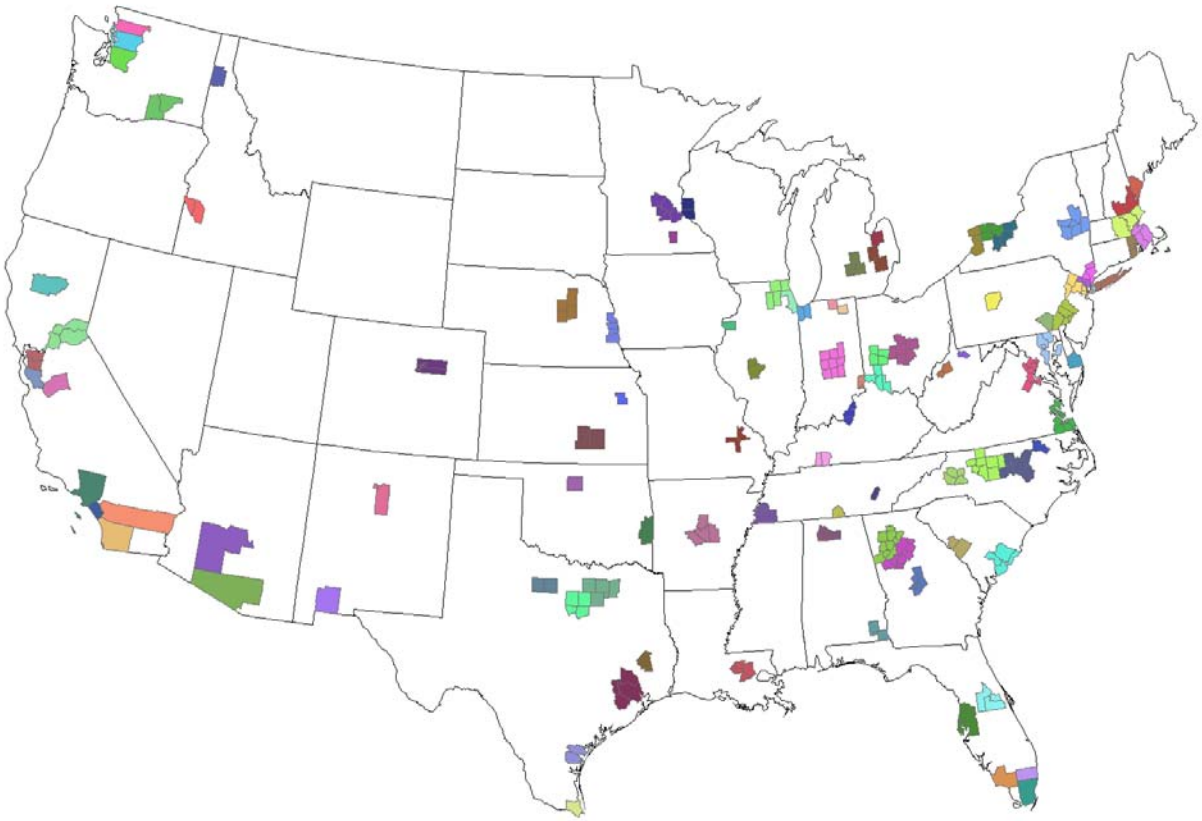
  -XRF testing for lead in paint

  -Wipe sampling for lead, arsenic and pesticides in dust

  -Vacuum sampling for allergens

  -Soil sampling for lead and arsenic
- Sampling completed in 1,131 homes (June 2005 – March 2006)

PSU Map



RESULTS FOR LBP

- 37.1M homes with LBP (35%) vs. 37.9 (40%) in NSLAH
- LBP increases with age of housing

-1978-2005:	7%
-1960-1977:	24%
-1940-1959:	66%
-1939 or earlier:	86%

- Regional differences

-Northeast:	50%
-Midwest:	39%
-South:	28%
-West:	29%

LEAD IN CERAMIC SURFACES

- At least 7M homes have lead in ceramic surfaces
- Most post-1978 homes classified as LBP (74%) have lead in ceramic surfaces only
- 32.6M homes have lead in non-ceramic surfaces; 4.5 M in ceramic surfaces only
- Ceramic lead increases only slightly with age
- Lead in ceramic tile floors does not result in elevated lead in dust

SIGNIFICANT LBP HAZARDS

- Significantly deteriorated LBP **OR** lead-contaminated dust **OR** lead-contaminated bare soil
- 23.2 M homes (22%) with SLBPH, vs. 24.0M (25%) in NSLAH
- SLBPH increases with age:

- 1978-2005:	3%
- 1960-1977:	11%
- 1940-1959:	39%
- Before 1940:	67%

- Regional differences:

- Northeast:	37%
- Midwest:	27%
- South:	16%
- West:	14%

SIGNIFICANT DIFFERENCES between AHHS and NSLAH

- Both Interior and Exterior LBP/LBP Hazards
  - AHHS 16.2M (15%) LBP; 6.6M (6%) LBP Hazards
  - NSLAH 20.3M (21%) LBP; 8.9M (9%) LBP Hazards
- Deteriorated LBP 1960-1977
  - AHHS 3.0 M (10%) vs. NSLAH 0.9M (3%)
- Significant LBP Hazards – Multifamily
  - AHHS 1.2M (7%) vs. NSLAH 2.4M (19%)
- Maximum LBP decreased from NSLAH to AHHS
  - Homes with > 4 mg/cm^2 down from 17% to 12%

INTERIOR LEAD DUST

- Interior dust hazards (>40 µg/ft^2 on floors or > 250 µg/ft^2 on window sills) decreased from 15.5M (16%) in NSLAH to 13.7M (13%) in AHHS
- Mean dust lead levels by surface and age

	FLOOR	WINDOW SILL
1978-2005	0.6 µg/ft^2	14 µg/ft^2
1960-1977	1.7 µg/ft^2	27 µg/ft^2
1940-1959	5.6 µg/ft^2	230 µg/ft^2
Before 1940	11.5 µg/ft^2	584 µg/ft^2

INTERIOR LEAD DUST (cont.)

- Floor Dust Lead (FD µg/ft^2) vs. Sig. Deteriorated LBP (Pb mg/cm^2)

	$1 \leq Pb < 4$	$Pb \geq 4$
$0 \leq FD < 10$	56%	45%
$10 \leq FD < 40$	19%	22%
$40 \leq FD < 100$	9%	13%
$FD \geq 100$	16%	20%

SOIL LEAD

- SOIL LEAD HAZARD: > 9 ft^2 bare soil with $\geq$1,200 ppm lead or 400 ppm in play area
- Decreased from 6.5M (7%) in NSLAH to 3.8M (4%) in AHHS
- Mean Bare Soil Lead by Age of Housing

All ages	184 ppm
1978-2005	26 ppm
1960-1977	70 ppm
1940-1959	205 ppm
Before 1940	691 ppm

ARSENIC

- Less than 5% of homes had detectable levels ($\geq$5 µg/ft^2) of Arsenic in interior dust
- 83.3M homes (79%) had detectable levels of Arsenic in soil ($\geq$ 1 ppm)
- Mean soil Arsenic levels by Region

All regions	6.6 ppm
Northeast	8.7 ppm
Midwest	7.8 ppm
South	5.3 ppm
West	5.6 ppm

ARSENIC (cont.)

- Mean soil Arsenic levels by age of housing

All ages	6.6 ppm
1978-2005	5.6 ppm
1960-1977	6.4 ppm
1940-1959	7.0 ppm
Before 1940	8.6 ppm

- No significant differences in soil Arsenic levels by housing type, occupancy, income, race or ethnicity

SOIL ARSENIC and WOOD STRUCTURES

- Wood structures in the yard (decks, porches, steps, handrails, play equipment, fences or wood chips) do correlate with soil Arsenic levels

SOIL As	WOOD	NO WOOD
≥ 5 ppm	70%	49%
≥ 10 ppm	37%	21%
≥ 20 ppm	16%	8%
≥ 40 ppm	7%	3%

REGULATORY LIMITS FOR SOIL ARSENIC

- 19 States reporting residential action levels for Arsenic in soil; 12 are below 6.6 ppm, the national mean level
- 17 States reporting residential cleanup levels for soil Arsenic; 16 are below 20 ppm
- 11% of homes have soil Arsenic levels $\geq$ 20 ppm
- 5% of homes have soil Arsenic levels $\geq$ 40 ppm

Development of the Environmental Relative Moldiness Index^{sm} Based on the AHHS

STEVE VESPER
US EPA

NOTICE

The U.S. Environmental Protection Agency (EPA) through its Office of Research and Development, funded and collaborated in the research described here. It has been subjected to the Agency's peer review and has been approved as an EPA publication.
Mention of trade names or commercial products does not constitute endorsement or recommendation by the EPA for use.

AGENDA

1. Describe mold specific quantitative PCR (MSQPCR)

2. Describe standard dust sampling protocol and the Environmental Relative Moldiness Index (ERMI) developed, based on AHHS

New Technology

- MSQPCR is “mold specific quantitative polymerase chain reaction”- PCR is a method for replicating DNA (i.e. polymerization)
- Based on unique DNA sequence for each mold species (Patent # 6,387,652). Full disclosure: Yes, EPA has a financial interest in use of the technology.

POLYMERIZATION

Forward Primer

AfumiF1: 5' - GCCCGCCGTTTCGAC

PROBE

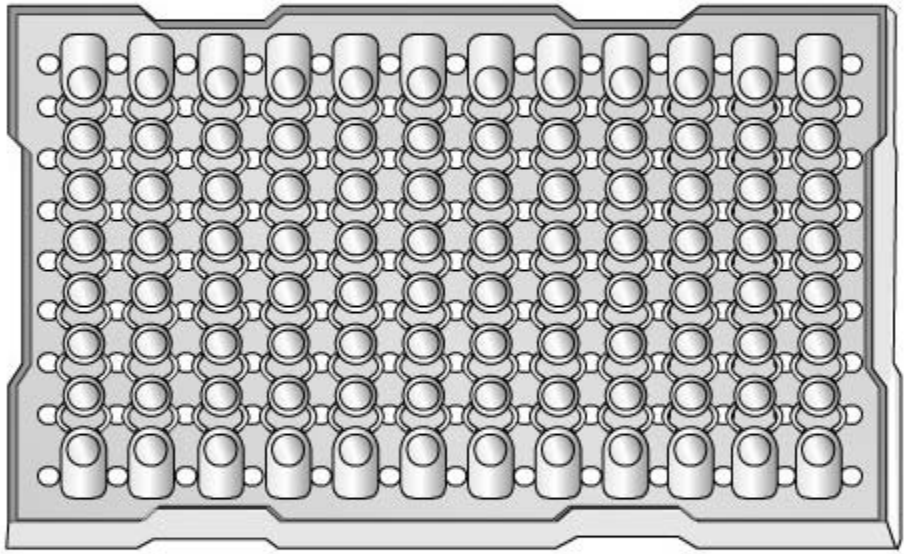
AfumiP1: 5' - CCCGCCGA'AGACCCCAACATG

AfumiR1: 5' - CCGTTGTTGAAAGTTTTAACTGATTAC

Reverse Primer

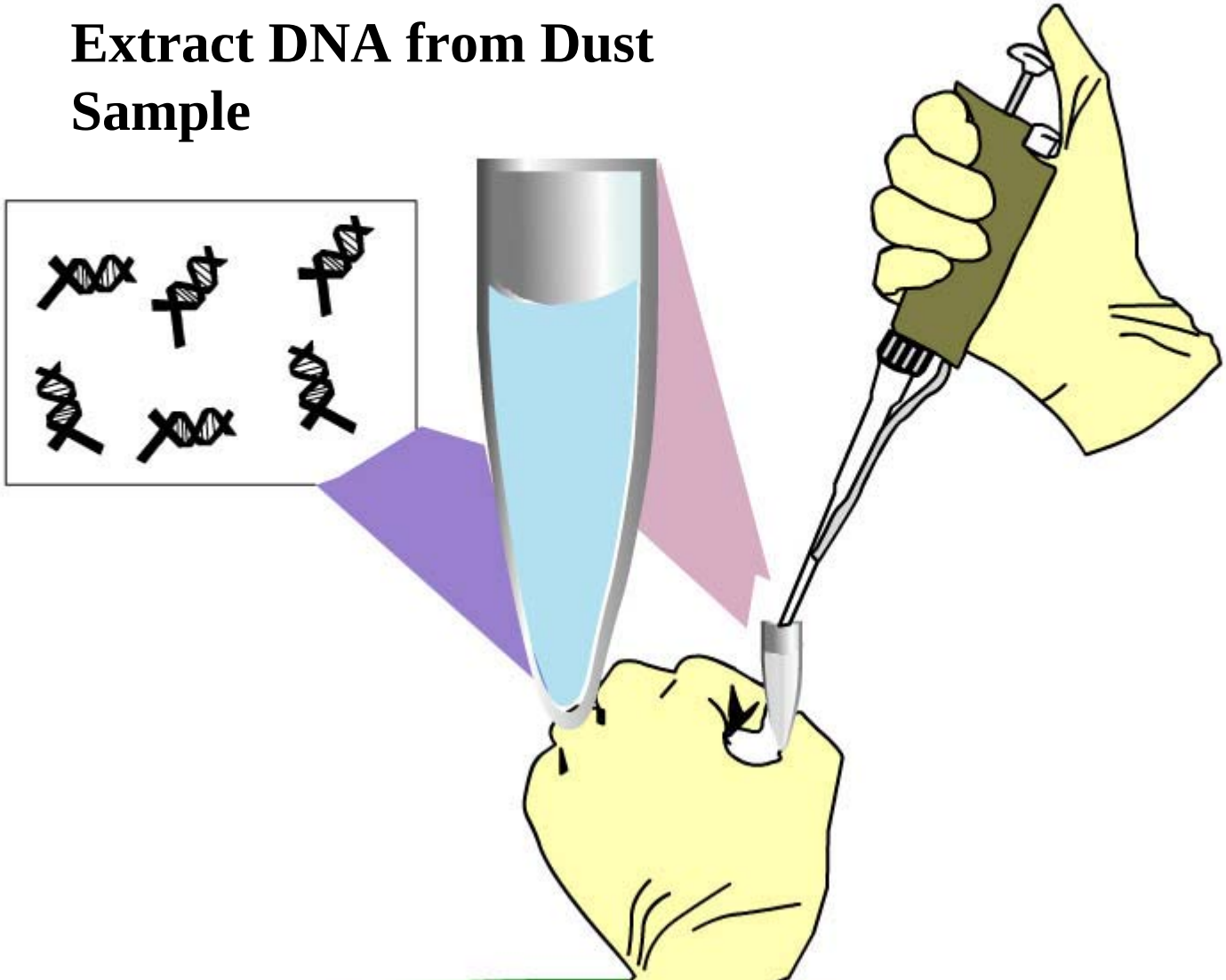
Sequence Detector

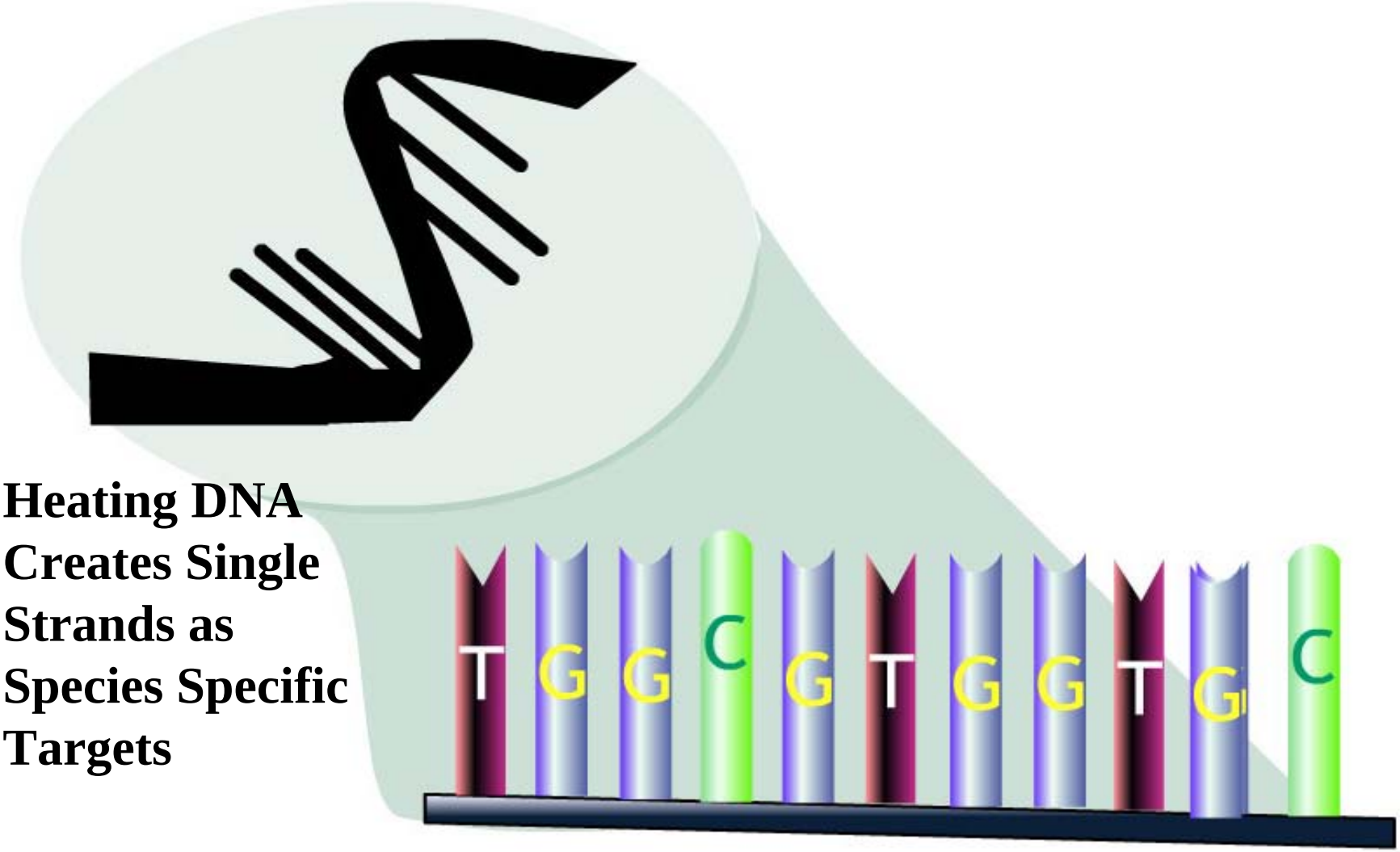
- **Removes the Human Element from Mold Analysis**



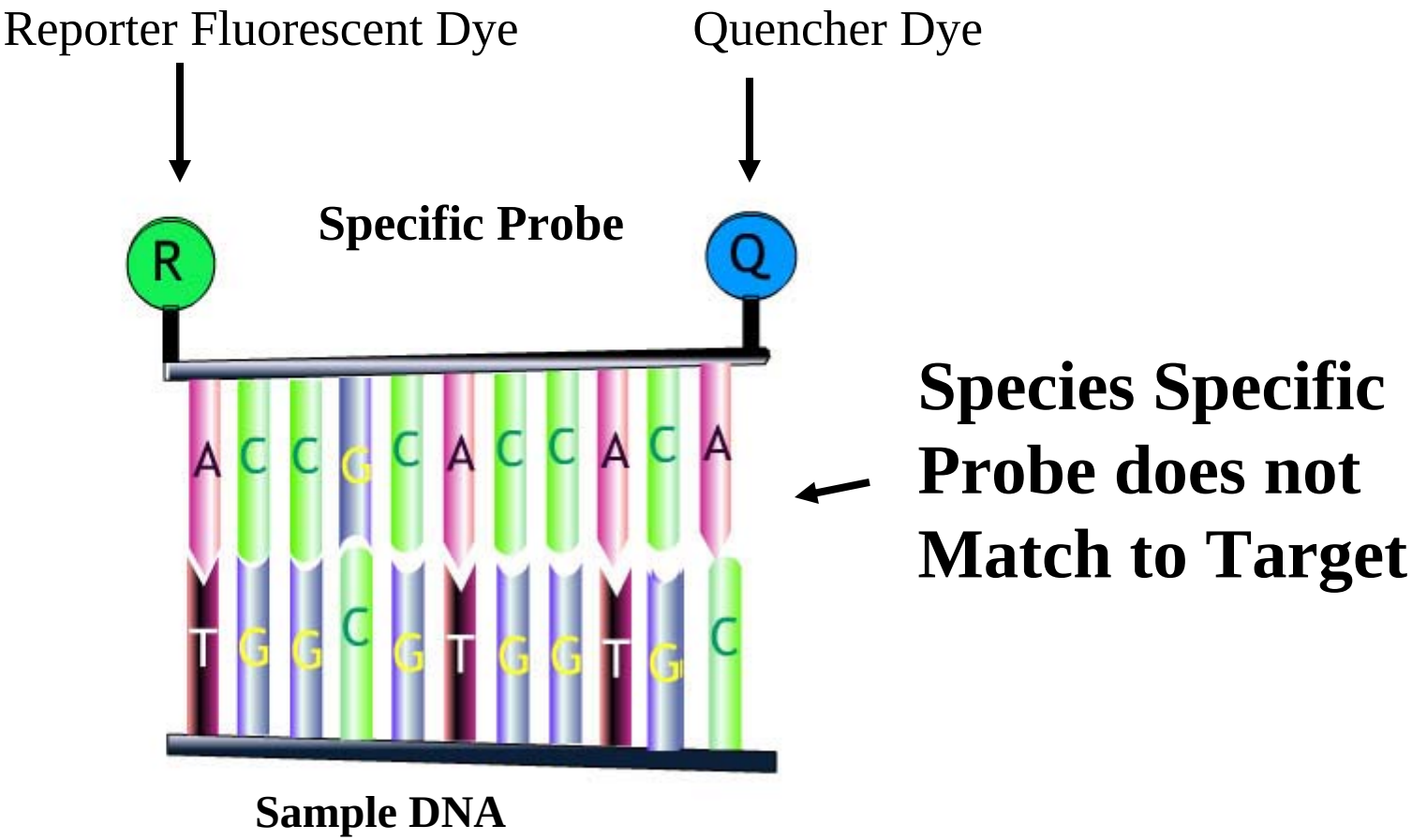
96–well Plate Format

Extract DNA from Dust Sample

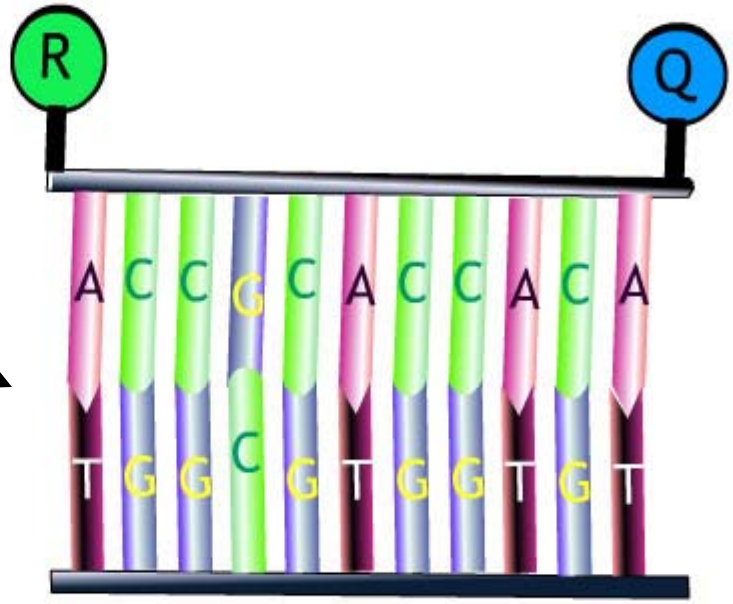


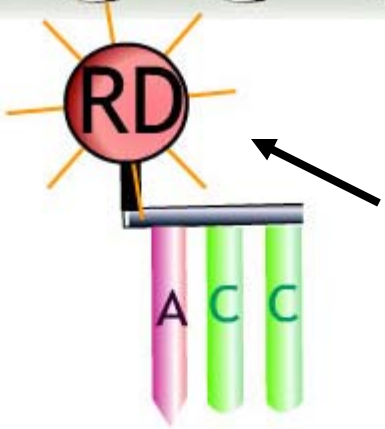


Heating DNA Creates Single Strands as Species Specific Targets

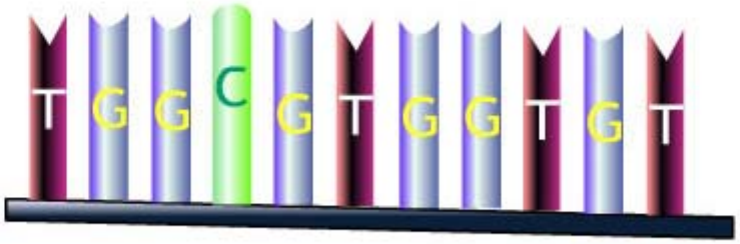

Reporter Fluorescent Dye
Quencher Dye
Specific Probe
R
Q
A C C G C A C C A C A
T G G C G T G G T G C
Sample DNA
Species Specific Probe does not Match to Target

Species Specific Probe Matches Target Exactly





If there is a match, then florescence is measured by the Sequence Detector.



AHHS PROTOCOL:

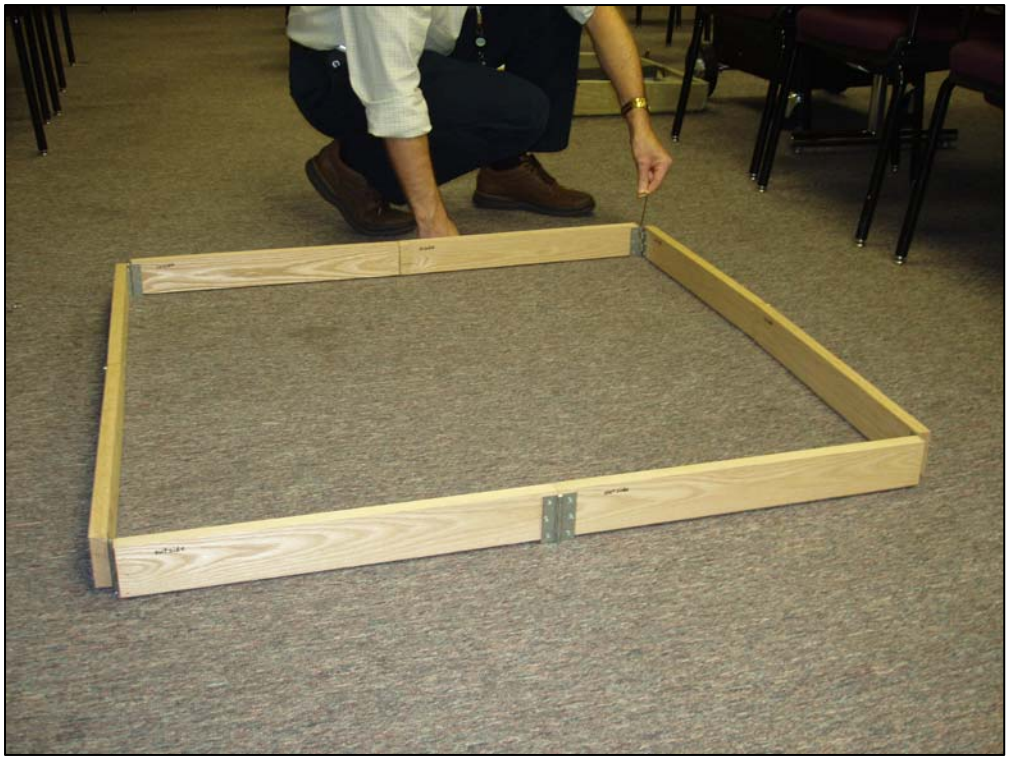
DUST SAMPLING

Collection Device

Fig. 4 Indoor Biotechnologies Mitest Dust Collector ©.

AREA SAMPLED

1. Vacuum 2 square meters in living room and in bedroom.



2. Need 5 mg sieved dust.

The Environmental Relative Moldiness Index-ERMI

National HUD American Healthy Home Survey, 1096 homes analyzed.

Mold Groups

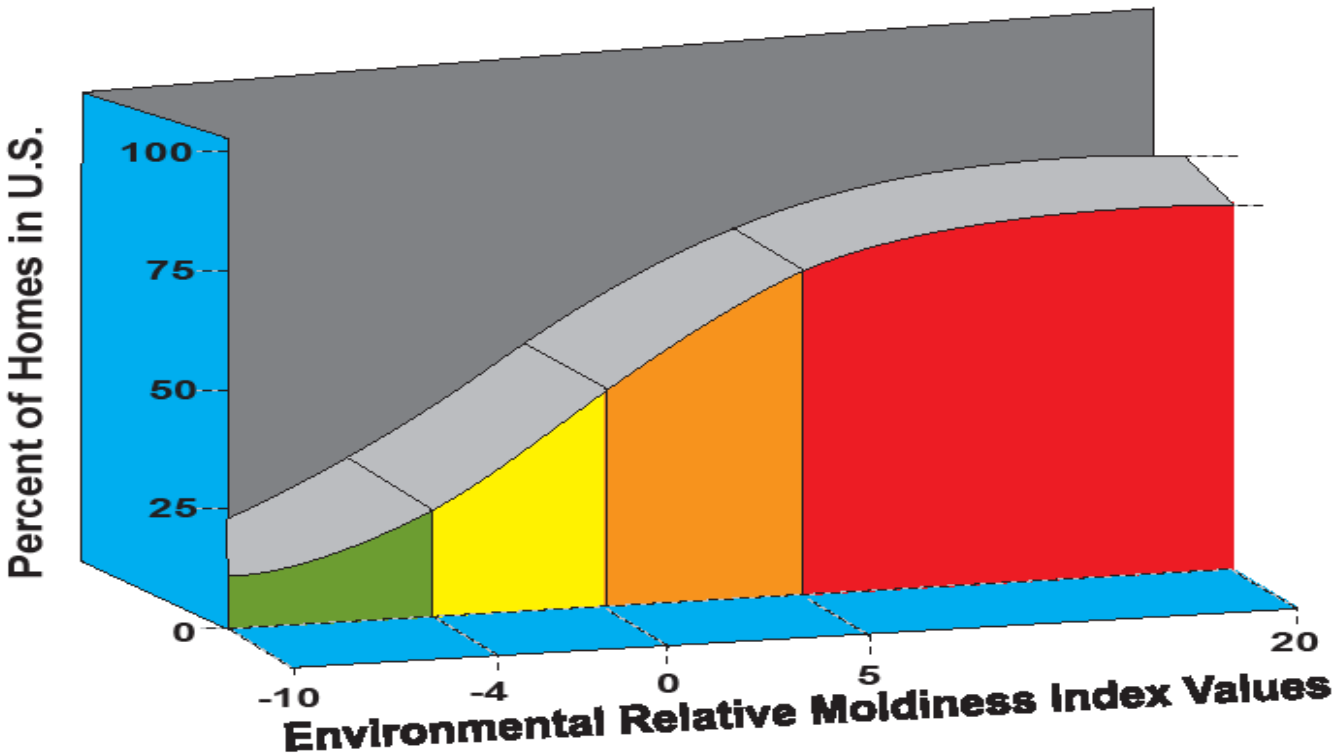
1. **The ERMI panel is total of 36 species, reduced from a total of 82 tested for originally.** **(Vesper et al. Journal of Occupational and Environmental Medicine. In Press)**
2. **Group 1 Molds, 26 species, associated with water-damaged environments.**
3. **Group 2 Molds, 10 species, are independent of water damage.**

ERMI Calculation

- **Sum of the logs (e.g. Log 1000 = 3; 100 = 2; 612 = 2.79 etc.) of the concentrations of Group 1 species minus the sum of the logs of the concentrations of the Group 2 species.** **(Vesper SJ et al. Journal of Occupational and Environmental Medicine. 2004:46;596-601. and Meklin T et al. Journal of Environmental Monitoring. 2004:6;615-620.**)

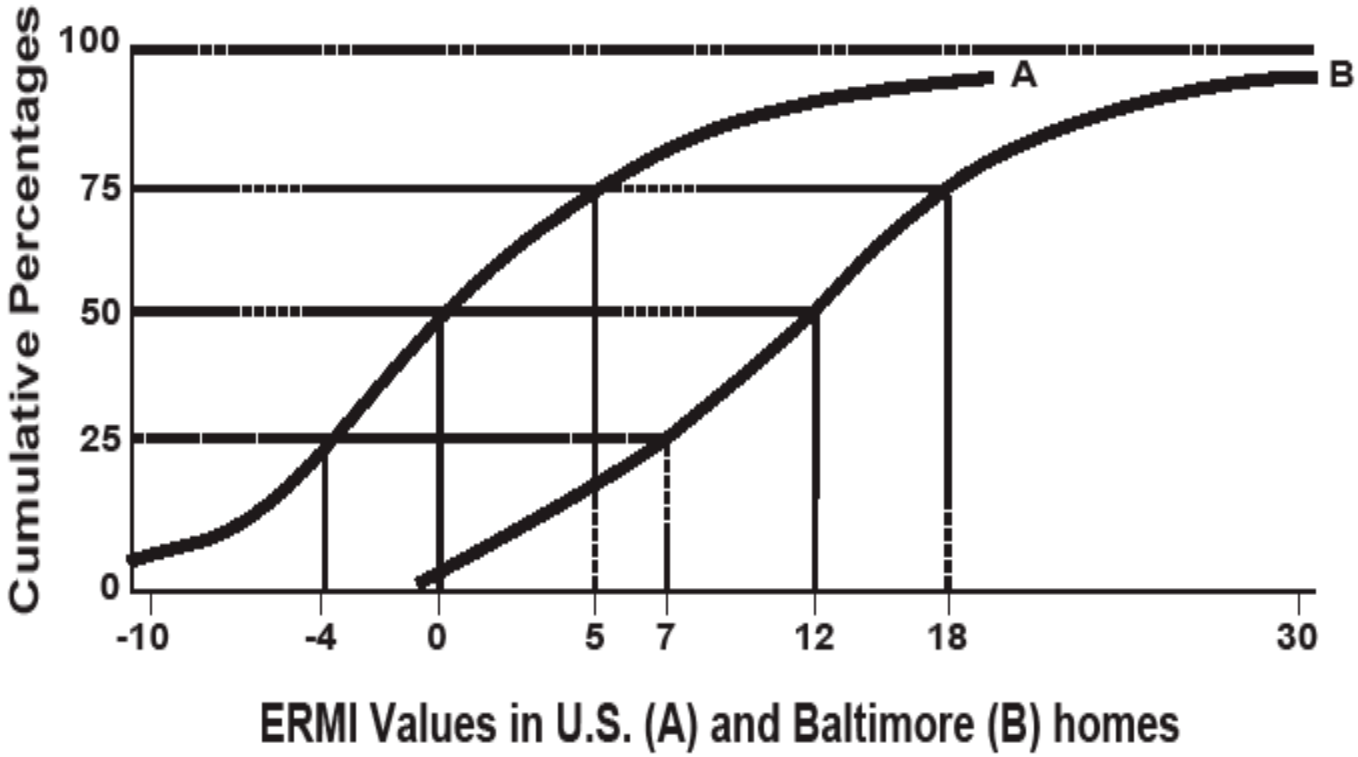
- **Assemble ERMI values from lowest to highest and divide into quartiles to create the "Environmental Relative Moldiness Index (ERMI) scale** **(Published: Vesper et al. Journal of Occupational and Environmental Medicine 2007; 49:829-833.)**

ERMI Scale


Percent of Homes in U.S.
100
75
50
25
0
-10
-4
0
5
20
Environmental Relative Moldiness Index Values

Group 1	House A	House B
Aspergillus flavus/oryzae	ND	<1
Aspergillus fumigatus	<1	1
Aspergillus niger	<1	ND
Aspergillus ochraceus	ND	11
Aspergillus penicillioides	81	4600
*Aspergillus restrictus**	ND	ND
Aspergillus sclerotiorum	ND	13
Aspergillus sydowii	ND	ND
Aspergillus unquis	ND	ND
Aspergillus versicolor	ND	56
Aureobasidium pullulans	610	450
Chaetomium globosum	1	5
Cladosporium sphaerospermum	<1	24
*Eurotium (Asp.) amstelodami**	16	3600
Paecilomyces variotii	ND	ND
Penicillium brevicompactum	19	34
Penicillium corylophilum	ND	ND
*Penicillium crustosum**	ND	ND
Penicillium purpurogenum	ND	1
*Penicillium spinulosum**	ND	ND
Penicillium variabile	ND	6
Scopulariopsis brevicaulis/fusca	3	43
Scopulariopsis chartarum	ND	3
Stachybotrys chartarum	ND	1
*Trichoderma viride**	ND	3
Wallemia sebi	8	2400
Sum of Logs Group I:	**8.56**	**24.13**

Group 2	House A	House B
Acremonium strictum	ND	1
Alternaria alternata	ND	ND
Aspergillus ustus	ND	1
Cladosporium cladosporioides 1	31	140
Cladosporium cladosporioides 2	1	4
Cladosporium herbarum	87	13
Epicoccum nigrum	37	570
*Mucor amphibiorum**	2	22
Penicillium chrysogenum	1	ND
Rhizopus stolonifer	<1	<1
Sum of Logs Group II:	**5.30**	**7.96**
ERMI :	**3.26**	**16.17**


Cumulative Percentages
100
75
50
25
0
A
B
-10
-4
0
5
7
12
18
30
ERMI Values in U.S. (A) and Baltimore (B) homes

Conclusions

1. The ERMI scale is the result of a standardized sampling protocol and DNA-based analysis of a National survey of US homes.
2. The ERMI scale provides a simple, objective method for estimating mold contamination.