Interim Findings on Formaldehyde Levels in FEMA-Supplied Travel Trailers, Park Models, and Mobile Homes

from the Centers for Disease Control and Prevention

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Summary

This interim report of a CDC study provides information about formaldehyde levels in a random sample of FEMA-supplied occupied travel trailers, park models, and mobile homes still being used as of December 2007 and January 2008 as temporary shelter for residents of the U.S. Gulf Coast region displaced by Hurricanes Katrina and Rita. Additional analyses on this study; and additional peer review of the study, its results, and conclusions; are ongoing. A final report on this study will be published in the spring 2008. In addition, other studies related to the health of persons displaced by Hurricanes Katrina and Rita and to formaldehyde levels in travel trailers, park models, and mobile homes are ongoing. However, this interim report suggests that formaldehyde levels in many of the travel trailers, park models, and mobile homes (geometric mean 77 parts per billion [ppb] across all types with many levels higher than this average) are higher than typical U.S. background levels (e.g., approximately 10-30 ppb in indoor air). Therefore, actions should be taken now to limit further exposures to residents. (For specific information, see the report sections below on recommendations to residents and recommendations to public officials).

Background

From December 21, 2007, to January 23, 2008, the Centers for Disease Control and Prevention (CDC) conducted testing to assess levels of formaldehyde in indoor air of a random sample of occupied travel trailers, park models, and mobile homes supplied by the Federal Emergency Management Agency (FEMA) as temporary housing for residents of the U.S. Gulf Coast region displaced by Hurricanes Katrina and Rita. The testing was one of several actions CDC initiated in response to a request from FEMA on July 13, 2007; to investigate concerns about formaldehyde in occupied FEMA-supplied travel trailers, park models, and mobile homes in Louisiana and Mississippi.

Objectives

The objectives of this study were:

1. To determine formaldehyde levels in occupied travel trailers, park models, and mobile homes.
2. To determine factors or characteristics of occupied travel trailers, park models, and mobile homes that could affect formaldehyde measurements.
3. To provide information to assist FEMA in making decisions about when and how to relocate residents from these FEMA-supplied travel trailers, park models, and mobile homes still used in the Gulf Coast area.

It is also important to understand that this study does not address the following:

1. The results should not be applied to travel trailers, park models, or mobile homes

purchased and used in other places and situations because the sample for this study was selected only from FEMA-supplied travel trailers, park models, and mobile homes used in the Gulf Coast region. Other travel trailers, park models, and mobile homes used elsewhere could differ based on their age, the characteristics of their manufacture, the circumstances of their use, or the characteristics of their environment.

2. This is a study of formaldehyde levels, and as such does not assess the health status of persons currently living in FEMA-supplied travel trailers, park models, and mobile homes.

Methods

Definitions

- **Mobile homes** are generally wider than 8 feet and/or longer than 40 feet (for an area greater than 320 square feet). They are built on permanent chassis; contain plumbing, heating, air-conditioning, and electrical systems; and are designed to be used as permanent homes. They are defined and regulated by the U.S. Department of Housing and Urban Development (HUD).
- **Travel trailers** are wheel-mounted trailers designed to provide temporary living quarters during periods of recreation, camping, or travel. Travel trailers generally have size limits, such as no larger 8 feet in width and 40 feet in length, for an area of less than 320 square feet. Travel trailers are generally considered vehicles rather than structures, and they are regulated by state transportation authorities rather than housing authorities.
- **Park models** are larger versions of a travel trailers (up to 400 square feet in area), that are used as temporary living quarters. Park Models are manufactured housing which are administratively exempted from HUD construction standards and are therefore typically regulated by transportation authorities and by manufacturer acceptance of a voluntary American National Standards Institute (ANSI) standard applying to their construction.

Selecting the study population and travel trailers, park models, and mobile homes

CDC randomly selected 519 travel trailers, park models, and mobile homes for testing using a FEMA-provided list of the 46,970 occupied travel trailers, park models, and mobile homes in Mississippi and Louisiana as of November 2007. The number of travel trailers, park models, and mobile homes chosen to be studied was based on power calculations designed to allow researchers to draw statistically valid conclusions for the population being studied (i.e., FEMA-supplied travel trailers, park models, and mobile homes being used in the Gulf Coast region) and for common types of travel trailers, park models, and mobile homes within that population of FEMA-supplied travel trailers, park models, and mobile homes. Disproportionate stratified random sampling was used to select travel trailers, park models, and mobile homes for testing.

The travel trailers, park models, and mobile homes were divided into 11 strata defined by the type of unit most commonly used: travel trailer, mobile home, and park model. The travel-trailer type was divided into seven strata defined by the top six brands[1] (Gulfstream, Forest River, Fleetwood, Fleetwood CA, Pilgrim, and Keystone) that together represented 61% of the occupied travel trailers, park models, and mobile homes being used. The seventh travel-trailer stratum included a combination of all other travel-trailer brands supplied by FEMA. The park-model type had two strata: the most common brand, Silver Creek, that represented 21% of the park models being used, and all other park model brands. The mobile-home type also was divided into two strata: the most common brand, Cavalier, that represented 17% of the mobile homes being used, and all

[1] Note: some brands may be made by more than one manufacturer

other brands. In addition, as the brand of travel trailer in most frequent use by FEMA, the Gulfstream travel-trailer stratum was oversampled.[2]

Study personnel telephoned and enrolled adult occupants for participation in the study according to procedures defined in the study protocol.[3] All participants in the study were required to be older than18 years of age, reside in a FEMA-supplied travel trailer, park model, or mobile home in Mississippi or Louisiana at the time of phone recruitment, and spend at least 6 hours each day in that trailer. If the adult resident declined to participate or was otherwise ineligible, personnel contacted residents of the next travel trailer, park model, or mobile home on the randomized list. When an adult resident agreed to participate, a time was scheduled to conduct the sampling.

Formaldehyde measurement

Trained study personnel and FEMA field workers were present for each scheduled sampling appointment. Staff collected a 1-hour sample of air for formaldehyde in each participating travel trailer, park model, or mobile home using the National Institute of Occupational Safety and Health (NIOSH) Manual of Analytical Methods (NMAM) Method 2016 with Supelco S10 LpDNPH cartridges. They also measured indoor temperature and relative humidity during the sampling period. Residents were asked to configure doors and windows as they would have them while they slept.

[2] Further information on the numbers of trailers in each stratum is shown in Table 2.
[3] Available at http://www.cdc.gov/nceh/ehhe/trailerstudy/

Air samples were collected using standard industrial hygiene pumps. Samples were drawn at a flow rate of 500±50 milliliters per minute for 1 hour. The sampling filter was placed at a height of 4 feet in a central location. One of the trained study personnel observed the sample collection at all times. No cooking or smoking was allowed in the travel trailers, park models, and mobile homes during the 1-hour sample collection period because these activities could have increased formaldehyde levels. Study personnel followed all quality assurance and quality control procedures. Samples were analyzed for formaldehyde levels at the Bureau Veritas laboratory in Novi, Michigan. The Bureau Veritas laboratory is the contract laboratory for NIOSH and has experience with NIOSH data quality objectives.

Additional information about the residents and the travel trailers, park models, and mobile homes

In addition to formaldehyde sampling, a short questionnaire was administered to an adult resident during the 1-hour sample collection process. Information collected in the questionnaire included occupant demographics, unit characteristics, and activities of inhabitants. Study personnel conducted an environmental walk-through survey, observing the unit for factors such as holes and leaks, mold, type of cooking fuel, and working smoke detectors.

Statistical analysis

All statistical analyses were conducted with SAS version 9.1. SAS SURVEYREG, SURVEYMEANS, and SURVEYFREQ were used to account for stratified sampling. Measures of central tendency were expressed as geometric means.[4] Regression models were constructed to assess the influence of temperature, smoking, and selected ventilation properties (i.e., whether windows, scuttles, or doors were open) on the main findings. Fuller analyses that attempt to explain variability in formaldehyde levels are pending and will be presented in the final report.

Consent and human subjects protections

This study was reviewed and approved by the CDC Institutional Review Board, and all human subjects provided informed consent and received appropriate notification of confidentiality.

Results

Overall range and variability of formaldehyde levels

[4] Simple averages (arithmetic means) are not suitable for representing "average" conditions when observations are clustered at one end of the data range. The occurrence of a few high numbers would result in a perceived "average" far higher than a number that would reflect actual conditions. In such situations statisticians use the geometric mean to represent a more accurate estimate of typical conditions. The geometric mean is calculated by adding the logarithms of the individual values, calculating their arithmetic mean, and taking the antilogarithm of the result.

The overall geometric mean (GM) formaldehyde level for all travel trailers, park models, and mobile homes sampled was 77 parts per billion (ppb) with a 95% Confidence Interval (CI) of 69 to 85 and a range of 3 to 590 ppb. The GM formaldehyde level was 81 ppb among travel trailers, 59 ppb among mobile homes, and 40 ppb among park models (Figure 1). The GM formaldehyde levels varied significantly between between travel trailers, park models, and mobile homes, but a wide range of formaldehyde levels were found in each of the three types. All three types contained some units with levels that were elevated (Table 1) relative to usual U.S. background levels (i.e., levels to which persons typically are exposed during daily life, typically 10- 30 ppb in indoor air).[5]

Variability in formaldehyde levels within and across travel-trailer, park-model, or mobile-home types

Different brands of travel trailers, park models, and mobile homes varied in average formaldehyde levels, but each stratum included some units with levels higher than U.S. background levels (Table 2). Except as noted below, controlling for smoking, open windows, temperature, and relative humidity did not change the statistical significance of these relationships.

The travel trailer brands Gulfstream, Keystone, and Pilgrim were not significantly different from each other but each showed statistically significantly higher levels of

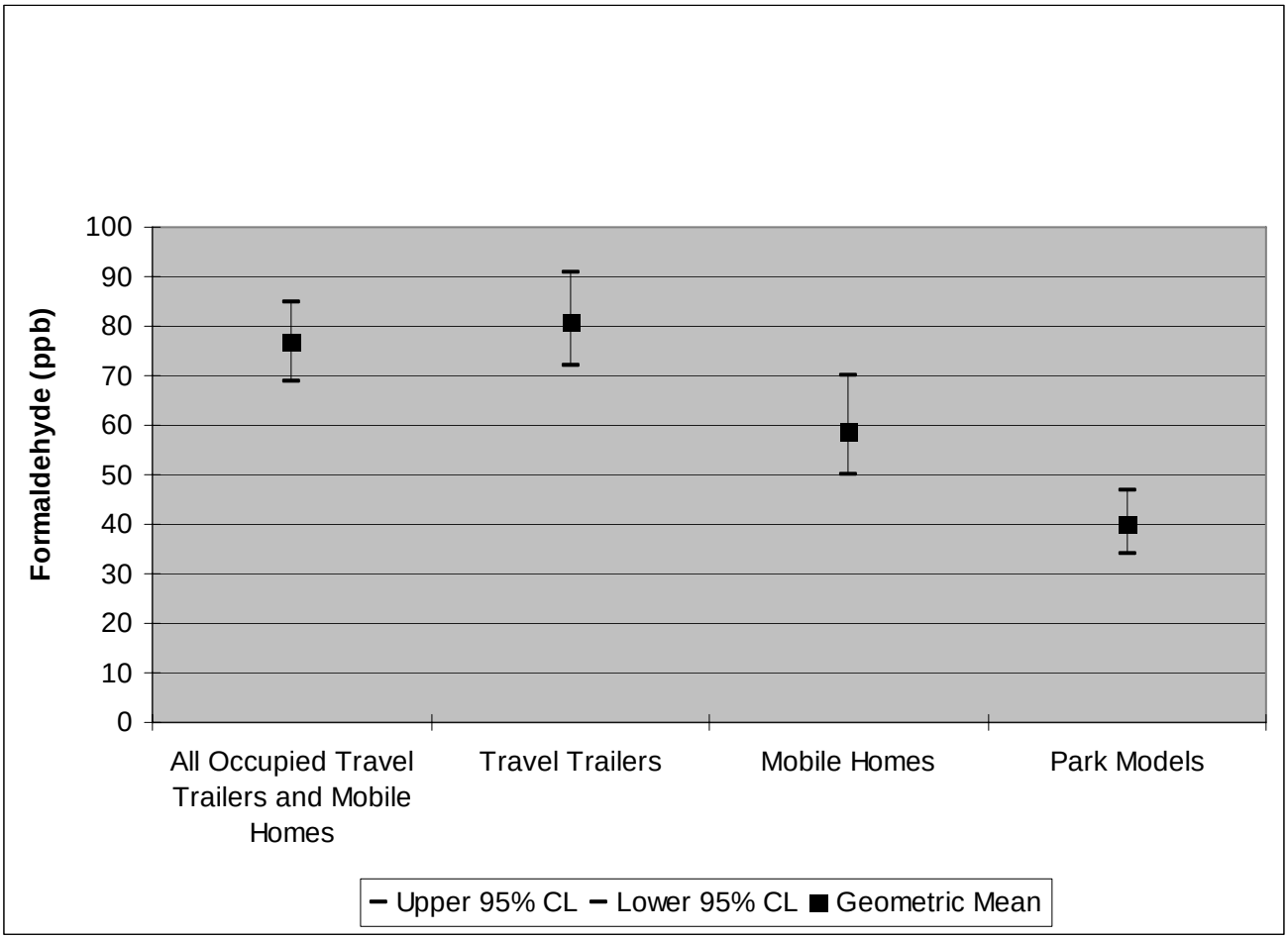
[5] More information about expected background levels is presented in the section on interpreting formaldehyde levels, below.

formaldehyde than the other travel-trailer strata combined. After adjusting for smoking, windows being open, temperature, and humidity, Forest River travel trailers also had significantly higher formaldehyde levels as compared with all other travel trailers combined. Travel trailers from Fleetwood and Fleetwood CA each showed statistically significantly lower levels of formaldehyde compared with the other travel-trailer strata combined, but they were not significantly different from each other.

Park models from Silver Creek showed statistically significant lower levels of formaldehyde compared with the other/unknown park-model stratum.

Unadjusted comparisons of mobile homes from Cavalier to other mobile homes showed statistically significantly higher levels of formaldehyde compared with the other mobile home stratum. However, this difference became non-significant after controlling for smoking, windows being open, temperature, and relative humidity. Thus, at least part of this apparent difference by brand appears to have been due to other confounding factors.

Figure 1. Geometric Mean Formaldehyde Levels in Occupied FEMA-Supplied Travel Trailers, Park Models, and Mobile Homes, Louisiana and Mississippi, December 2007 to January 2008



*GM = Geometric Mean; ppb = parts per billion (divide by 1000 to get parts per million); CL = Confidence Limit.

Table 1. Formaldehyde Levels in 519 Occupied FEMA-Supplied Travel trailers, Park Models, and Mobile Homes in Louisiana and Mississippi, December 2007 to January 2008

Unit Type	n in sample	Formaldehyde GM (ppb)*	Range (ppb)	95 % CI for GM (ppb)	Weighted Percent of the sample with levels ≥	
					100 ppb	300 ppb
Travel Trailer	358	81	3–590	72, 91	41%	6%
Park Model	82	40	3–170	34, 47	9%	0%
Mobile Home	79	59	11–320	50, 70	17%	0%

*GM = Geometric Mean; ppb = parts per billion (divide by 1000 to get parts per million); CI = Confidence Interval.

Table 2. Formaldehyde Levels by Brand in 519 Occupied FEMA-supplied Travel Trailers, Park Models, and Mobile Homes in Louisiana and Mississippi, December 2007 to January 2008

Unit Type	Brand	N in stratum	n in sample	Formaldehyde GM (ppb)*	Range (ppb)	95 % CI for GM (ppb)	Percent of the sample with levels ≥	
							100 ppb	300 ppb
Travel Trailer	Gulfstream	14, 624	121	103	3–580	87, 121	56%	8%
	Forest River	3,220	39	85	17–510	65, 110	44%	5%
	Fleetwood	2,371	44	39	3–140	31, 48	7%	0%
	Fleetwood CA	1,699	38	42	7–300	33, 53	11%	3%
	Pilgrim	1,584	39	108	25–520	85, 136	51%	3%
	Keystone	1,395	38	102	23–480	79, 131	53%	11%
	Other TTs	15,637	39	73	11–590	56, 95	33%	5%
Park Model	Silver Creek	224	38	33	3–100	27, 39	3%	0%
	Other PMs	809	44	42	11–170	35, 51	11%	0%
Mobile Home	Cavalier	921	40	78	14–320	64, 96	38%	3%
	Other MHs	4,486	39	56	11–260	46, 68	13%	0%
	Total	46,970	519	77	3–590	69, 85		

*GM = Geometric Mean; ppb = parts per billion (divide by 1000 to get parts per million); CI = Confidence Interval.

Discussion

This is an interim report of the formaldehyde levels in indoor air from December 2007 to January 2008 in a sample of FEMA-supplied occupied travel trailers, park models, and mobile homes in Louisiana and Mississippi. The final report, which will contain additional analyses and be subject to additional peer review, will be published in the spring 2008.

Key Findings

1) In many travel trailers, mobile homes, and park models tested, formaldehyde levels were elevated relative to typical levels of U.S. indoor exposure. (See section below on interpreting formaldehyde levels for a fuller discussion).

2) Average level of formaldehyde in all units was about 77 ppb and many units had levels that were higher than this average. These levels are higher than U.S. background levels, and at the levels recorded in many travel trailers, park models, and mobile homes health could be affected. Measured levels ranged from 3 ppb to 590 ppb.

3) These measured levels are likely to under-represent long-term exposures because formaldehyde levels tend to be higher in newly constructed travel trailers, park models, and mobile homes and during warm weather.

4) Higher indoor temperatures were associated with higher formaldehyde levels in this study independent of unit type or brand.

5) Formaldehyde levels varied by unit type (travel trailers, mobile homes, and park

models), but all types of travel trailers, park models, and mobile homes tested had some levels higher than usual U.S. background levels.

6) Travel trailers had significantly higher average formaldehyde levels than park models or mobile homes in this study. Travel trailers also had higher proportions of units with formaldehyde levels higher than 100 and 300 ppb than park models or mobile homes in this study.

7) Because some types and brands had lower average formaldehyde levels, there might be ways to manufacture or use travel trailers, park models, and mobile homes in ways that reduce exposures. Additional studies are ongoing that seek to shed additional light on this question.

Interpreting Formaldehyde Levels in Indoor Air

The formaldehyde levels found in travel trailers, mobile homes, and park models in this study were elevated relative to typical background levels. In outdoor air, background formaldehyde levels are below 10 ppb, although on busy city streets levels they can reach the range of 20–40 ppb. Indoor air concentrations in conventional homes typically range from 10–30 ppb. Industrial workplaces can have much higher levels, such as in the range of 1,000 ppb or higher.

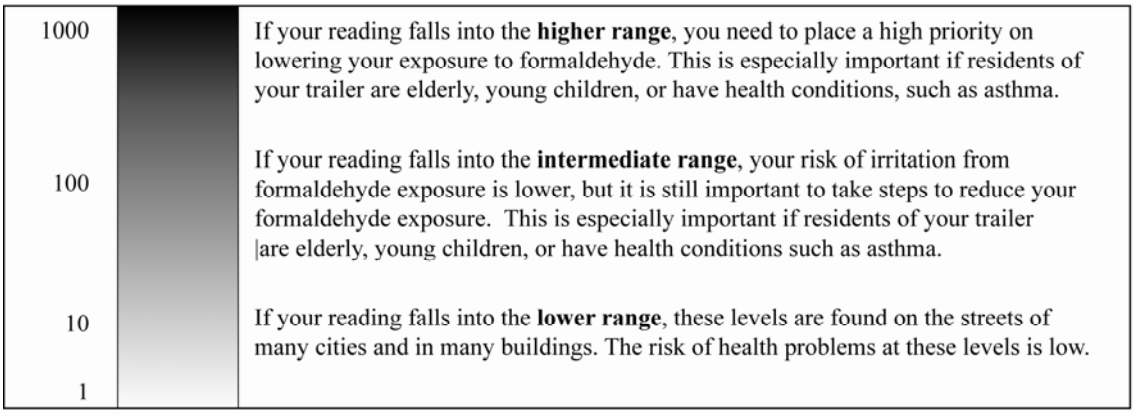
What do formaldehyde levels mean for health? There is no specific level of formaldehyde that separates "safe" from "dangerous."[6] As the formaldehyde level rises,

[6] We have not cited here the various exposure limits that have been developed for formaldehyde because they are widely variable and none relate directly to occupied trailers.

the risk of health consequences rises. At higher levels, people could have acute symptoms such as coughing and irritated eyes and throat. Even at levels too low to cause such symptoms, there could be an increased risk of cancer.

Other factors also contribute to risk, including how much time is spent in the trailer; the age of the occupants, especially if they are very old or very young; and the presence of chronic diseases such as asthma. The ranges of formaldehyde levels, from low single digits up to 1,000 ppb, are shown in Figure 2. At the lower ranges the health risk is quite low, and at the higher range the health risk is substantially higher. This is both for acute symptoms, such as coughing, and for long-term effects, such as cancer. Assessing individual risk and planning ways to reduce risk should be done in consultation with a health professional.

Figure 2: Interpreting the Significance of Formaldehyde Levels



Note: Levels are expressed at parts per billion (ppb). To convert to parts per million (ppm), divide by 1000.

Strengths of This Study

1. The sample of travel trailers, park models, and mobile homes was selected so that statistically valid conclusions could be drawn that would apply to all occupied FEMA-provided travel trailers, park models, and mobile homes in Louisiana and Mississippi. Further, the sample was developed so that statistically valid results could be obtained by unit type and brand.
2. These data were collected using a NIOSH-published and fully evaluated sampling method, and they have been evaluated through a quality assurance/quality control process.
3. The results of the statistical analysis and this report also received peer review inside CDC. Additional peer review will be conducted for the final report.
4. This preliminary report provides important and timely public health information to support ongoing decision making.

Challenges to Interpreting This Information

1. For travel trailers, park models, and mobile homes, no single formaldehyde level or standard exists that can easily distinguish safe from unsafe levels.
2. Formaldehyde levels are lower in cooler temperatures and lower humidity; therefore, levels measured in this study are likely to underestimate those that occurred in the past and those that would occur in the future during summer months.
3. Although average formaldehyde levels by unit type could be useful in helping to prioritize which residents might need to move most urgently, all types include units with relatively higher and lower formaldehyde levels.

4. As noted elsewhere in this report, the results of this study do not necessarily apply to travel trailers, park models, or mobile homes used in other places and situations because this sample was selected to apply only to FEMA-supplied travel trailers, park models, and mobile homes being used in Louisiana and Mississippi. Differences in formaldehyde levels by unit type or brand could reflect differences in unit age, manufacture, environment, or circumstances of use.

5. This study does not assess the health status of people currently living in FEMA-supplied travel trailers, park models, and mobile homes.

Recommendations for Public Health, Emergency Response, and Housing Officials

1) These conclusions support the need to move quickly, before weather in the region warms up, to relocate residents of the U.S. Gulf Coast region displaced by Hurricanes Katrina and Rita who still live in travel trailers, park models, and mobile homes. The highest priority (in order of precedence) should be persons who are

a. currently having symptoms that could be attributable to formaldehyde exposure

b. especially vulnerable (i.e., children, the elderly, and those with chronic diseases), and

c. living in unit types that tend to have higher formaldehyde levels.

2) Follow-up will require multi-agency collaboration—including among FEMA, HUD, CDC, state and local officials, and others—to achieve safe, healthy housing for people displaced by Hurricanes Katrina and Rita who continue to live in travel trailers, park models, and mobile homes.

3) Follow-up will require multi-agency collaboration involving HUD, CDC, the Department of Education, state and local officials, and others to assess the potential for formaldehyde exposure in travel trailers, park models, and mobile homes used in other places and contexts including travel trailers, park models, and mobile homes that are used for recreation, for permanent housing, and in schools.

4) Federal, state, and local officials should consider how best to provide necessary assistance to the Louisiana and Mississippi state health departments to ensure adequate follow-up, including medical needs, for residents with health and medical concerns resulting from formaldehyde exposure while residing in FEMA-provided travel trailers, park models, and mobile homes.

5) Federal, state, and local officials should consider supporting the establishment of a health registry of children and others who resided in travel trailers, park models, and mobile homes in the Gulf Coast region.

Recommendations for Residents Awaiting Relocation

1) Spend as much time as possible outdoors in fresh air.

2) Open windows as often as possible to let in fresh air.

3) Try to maintain the temperature inside travel trailers, park models, and mobile homes at the lowest comfortable level.

4) Do not smoke, especially not inside.

5) If you have health concerns, see a doctor or another medical professional.

6) All of these recommendations particularly apply to families that include children, the

elderly, and those with chronic diseases such as asthma.

Further CDC Action

1) CDC began notifying participants about the study results on February 21, 2008, with personal visits by members of the U.S. Public Health Service Commissioned Corps and FEMA representatives, and by hand-delivered letters.

2) At a series of "public availability sessions" in Louisiana and Mississippi, CDC staff will be available to talk with concerned and interested individuals to provide information and answer questions.

3) Other factors might affect formaldehyde levels, and CDC will be analyzing the data further to assess these factors. Further internal and external peer review of the data and conclusions is ongoing or planned. A final report on this study is expected later in the spring 2008. Understanding variability in formaldehyde levels is a key step in reducing ongoing exposures. Other work related to characterizing exposures and health effects among displaced residents is continuing.

4) CDC is assessing formaldehyde levels across different models and types of unoccupied travel trailers, park models, and mobile homes to identify factors that reduce or heighten those levels. This assessment also involves identifying cost-effective ways to reduce or lower formaldehyde levels and concentrations in travel trailers, park models, and mobile homes.

5) CDC is developing a protocol for a long-term study of children who resided in FEMA-supplied travel trailers, park models, and mobile homes in Mississippi and

Louisiana.

6) CDC is providing educational materials and information to residents of travel trailers, park models, and mobile homes about their risk of exposure to formaldehyde and ways to improve indoor air quality and health.

7) CDC will reconvene the panel of experts it has used previously on this issue to identify and provide input on health issues that could be associated with long-term residence in travel trailers, park models, and mobile homes.

For Additional Information

Operators at CDC's 24-hour, toll-free telephone hotline will continue to respond to health-related questions from residents. The hotline number is 1-800-CDC-INFO (1-800-232-4636). Additional information is also available at www.cdc.gov/environmental.