# Exposure and risk disparities between Mexican-American and non-Hispanic white populations in Houston

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## SUMMARY
Mexican-Americans residing in Houston, Texas, may be exposed to higher personal concentrations of certain hazardous air pollutants (HAPs) than non-Hispanic Whites, and could therefore be disproportionately affected by the potential health risks that are associated with them. The personal exposure and cancer risk of 50 Mexican-American and 45 White adults living in Houston were assessed. A subset of personal air measurements of HAPs from the Relationship of Indoor, Outdoor, and Personal Air study was used: acetaldehyde, benzene, carbon tetrachloride, chloroform, ethylbenzene, formaldehyde, methyl tert-butyl ether, methylene chloride, p-dichlorobenzene (p-DCB), styrene, tetrachloroethylene, and trichloroethylene. Results suggest that Mexican-Americans were exposed to significantly higher concentrations of benzene, chloroform and p-DCB than Whites. Of these HAPs, p-DCB accounted for most of the differences in risk between the two groups. Indoor concentrations had a dominant role in determining personal exposures for both ethnic groups.

## KEYWORDS
Personal exposure, Cancer risk, p-Dichlorobenzene, Formaldehyde, Mexican-American

## INTRODUCTION
There is increasing evidence that disparities in environmental exposures may disproportionately affect the health of ethnic minorities. These groups seem to be exposed to higher concentrations of hazardous air pollutants (HAPs) and the potential cancer risks that are associated with them (Morello-Frosch and Jesdale, 2006). Studies of environmental health risks of minorities need to be integrated with exposure assessments that consider the contributions from the significant number of indoor sources of HAPs, and the large fraction of time people spend indoors. Moreover, results from the National Human Exposure Assessment Survey (NHEXAS) studies (Gordon et al., 1999), and the Relationship of Indoor, Outdoor, and Personal Air (RIOPA) study (Weisel et al., 2005a) clearly demonstrate that some indoor sources can have a greater impact on personal exposure to HAPs than outdoor sources.

Results from a limited number of exposure studies that included minorities suggest that specific HAPs could be affecting these groups disproportionately. The School Health Initiative: Environment, Learning, and Disease (SHIELD) study concluded that low-income Hispanic and Southeast Asian children had high upper-bound exposures of p-dichlorobenzene (p-DCB), and African-American and Hispanic children were exposed to elevated concentrations of chloroform (Adgate et al., 2004). The Toxics Exposure Assessment Columbia-Harvard (TEACH) study also determined that p-DCB was a large contributor to the cancer risk of urban African-American and Hispanic teenagers residing in New York City and Los Angeles (Sax et al. 2006). The Third National Health and Nutrition Examination Survey

(NHANES III) associated reduced pulmonary function among African-Americans and Mexican-Americans with high blood levels of p-DCB, which were attributed to chronic exposure to consumer products used indoors (Elliot et al., 2006).

The objective of the RIOPA study was to assess the contribution of outdoor and indoor sources of HAPs and particulate matter to personal exposures (Weisel et al., 2005a). Outdoor, indoor, and personal air samples were collected from approximately 100 non-smoking residences each in Elizabeth, New Jersey; Houston, Texas; and Los Angeles County, California. We focus in this article on adult participants from Houston, of whom 50 described themselves as Mexican-American and 45 as non-Hispanic White. We estimate their cancer risks based on their personal air concentrations for several volatile organic compounds (VOCs) and carbonyls, assess the contribution of each compound to their cumulative cancer risk, and compare the possible contribution of indoor and outdoor sources to personal air concentrations. Furthermore, we evaluate differences between Mexican-Americans and Whites that may influence disparities in personal concentrations and cancer risks.

## METHODS

RIOPA-Texas recruited non-smoking subjects residing in Houston, Texas, whose homes varied in proximity to major outdoor sources of pollution such as petrochemical facilities. Subjects included adult volunteers who worked at home or in their neighborhood, as well as children living in these homes. The present study includes only the adults. RIOPA-Texas was not designed as a probability-based population sample, so its results are not necessarily generalizable.

A detailed description of the RIOPA field and measurement protocols has been described by Weisel et al. (2005a; 2005b). Briefly, from 1999 to 2001, outdoor, indoor and personal air concentrations of 16 VOCs and 10 carbonyls, together with residential air exchange rates (AER), were measured during two separate 48-hour periods in each house, approximately three months apart. House characteristics (e.g., volume, temperature) and activity logs were also recorded. VOCs were sampled with Organic Vapor Monitors (OVM 3500, 3M Company, St. Paul, MN, USA) and analyzed by the method described by Chung et al. (1999). Airborne carbonyls were collected with both passive (85% of the samples) and active (15% of the samples) methods. Active samples were collected using 2,4-dinitrophenylhydrazine (DNPH). Passive samples were collected using the Passive Aldehydes and Ketones Samplers (PAKS), described by Zhang et al. (2001). Measurements from active and passive methods did not show statistically significant differences. This article focuses on the subset of HAPs sampled in RIOPA-Texas for which estimates of cancer potencies are available (see Table 1). The percentages of measurements for these HAPs that were above the method detection limits (MDLs) are also shown in Table 1.

Estimates of cancer risks for each HAP were derived as:

$$CR = ExUR \qquad (1)$$

where *CR* is the estimated cancer risk expressed as excess cancers per 1 million population based on exposures over a 70-year lifetime, *E* is the measured personal concentration ($\mu g/m^3$), and *UR* is the inhalation cancer unit risk or cancer potency ($m^3/\mu g$) (Table 1). The personal concentrations were averaged when the participant was sampled during two different occasions (90% of the Mexican-Americans and 82% of the Whites). The cumulative cancer risk (*CCR*) was calculated by adding the *CR* from each HAP (Caldwell et al., 1998).

The Wilcoxon rank-sum test was used for all statistical tests of differences. Differences were considered statistically significant at $p < 0.05$.

Table 1. Subset of RIOPA hazardous air pollutants with available cancer unit risks.

| Species | n | > MDL (%) | *UR* ($m^3/\mu g$) | Species | n | > MDL (%) | *UR* ($m^3/\mu g$) |
|---|---|---|---|---|---|---|---|
| Acetaldehyde [a] | 125 | 100 | $2.2x10^{-6}$ | Methylene chloride [a] | 199 | 74.4 | $4.7x10^{-7}$ |
| Benzene [a] | 199 | 100 | $7.8x10^{-6}$ | MTBE [b] | 199 | 98.5 | $2.6x10^{-7}$ |
| Carbon tetrachloride [a] | 199 | 99.5 | $1.5x10^{-5}$ | p-Dichlorobenzene [b] | 199 | 78.9 | $1.1x10^{-5}$ |
| Chloroform [a] | 199 | 93.0 | $2.3x10^{-5}$ | Styrene [c] | 199 | 89.9 | $5.0x10^{-7}$ |
| Ethylbenzene [b] | 199 | 99.5 | $2.5x10^{-6}$ | Trichloroethylene [b] | 199 | 28.6 | $2.0x10^{-6}$ |
| Formaldehyde [a] | 125 | 100 | $1.3x10^{-5}$ | Tetrachloroethylene [b] | 199 | 76.9 | $5.9x10^{-6}$ |

[a] Integrated Risk Information System (IRIS) (U.S. EPA, 2005), [b] California Office of Environmental Health Hazards Assessment (OEHHA) (CalEPA, 2002), [c] Caldwell et al. 1998. n: number of personal measurements. Abbreviations: MDL, method detection limit; *UR*, unit risk.

**RESULTS**

Participants spent approximately 82% of their time at home with no difference between the two ethnic groups. A summary of selected household characteristics is shown in Table 2. Most of the subjects were female: 92% of the Mexican-Americans and 73% of the Whites. Sixty-nine percent of Mexican-American households had incomes lower than \$25,000 per year, while seventy-nine percent of Whites earned more than this amount. Ninety-eight percent of the Mexican-Americans lived in either detached single-family houses (54%) or trailers (44%), while eighty-nine percent of Whites lived in single-family detached homes. At least 90% of the homes were older than 10 years. Differences in proximity to major industrial sources and potential indoor sources of HAPs are also summarized in Table 2. Similar percentages of Mexican-American and White households were located in the vicinity (i.e., ≤ 1 km) of major industrial sources of HAPs. For other potential sources, possible important dissimilarities were that more Mexican-Americans parked their cars in attached carports (82%), while Whites used either attached carports (39%) or attached garages (20%). Furthermore, during the study more Mexican-Americans reported using cleaning solutions (74%) than did Whites (46%). Among these participants, a larger percentage of Mexican-Americans (41%) used chlorine bleach than did Whites (21%). Lastly, reported use of air fresheners and moth repellents was more prevalent among Whites than Mexican-Americans.

Table 2. Selected characteristics from households in RIOPA-Texas.

| Household characteristic | Mex.-Am.(%)[1] | White (%)[2] | Household characteristic | Mex.-Am.(%)[1] | White (%)[2] |
|---|---|---|---|---|---|
| Female | 92 | 73 | Close to industrial sources | 88 | 82 |
| Male | 8 | 27 | Car in attached garage | 6 | 20 |
| *Income* | | | Car in attached carport | 82 | 39 |
| < \$25 K | 69 | 21 | | | |
| \$25-50 K | 21 | 34 | *Participant used* | | |
| > \$50 K | 10 | 45 | Cleaning solutions | 63 | 36 |
| *Bldg. type* | | | Cleaning solutions (other person) | 11 | 10 |
| Mobile home/trailer | 44 | 7 | Bleach (participant or other) | 41 | 21 |
| Single-family detached | 54 | 89 | Air fresheners | 38 | 76 |
| Single-family attached | 0 | 2 | Deodorizers | 53 | 49 |
| Apartment | 2 | 2 | Moth repellents | 9 | 20 |

n: number of measurements. [1] n=50; [2] n=45.

The houses in the study are described in more detail in Table 3. The Mexican-American households were considerably smaller and leakier ($V_{mean}$=210 $m^3$, $AER_{mean}$=0.77 $hr^{-1}$) than White residences ($V_{mean}$=390 $m^3$, $AER_{mean}$=0.52 $hr^{-1}$). There were no statistically significant differences in indoor temperature and relative humidity.

Table 3. Characteristics of Mexican-American and White residences in RIOPA-Texas.

| Criteria | Mexican-American | | | | White | | | | p-value[a] |
|---|---|---|---|---|---|---|---|---|---|
| | n | Mean | SD | Median | n | Mean | SD | Median | |
| Volume ($m^3$) | 46 | 210 | 75.9 | 200 | 44 | 390 | 287 | 327 | 0.000 |
| AER[b] ($hr^{-1}$) | 77 | 0.77 | 0.75 | 0.53 | 73 | 0.52 | 0.44 | 0.39 | 0.006 |
| Temp. (°C) | 82 | 23.9 | 4.10 | 23.9 | 74 | 24.1 | 2.60 | 24.0 | 0.450 |
| RH (%) | 48 | 53.5 | 9.52 | 53.8 | 51 | 53.6 | 10.8 | 54.6 | 0.420 |

n: number of measurements. AER measurements are for two seasons. Lower number of RH values was due to equipment malfunction. Abbreviations: SD, standard deviation; AER, air exchange rate; RH, relative humidity. [a] p-values based on the Wilcoxon rank-sum test ($p < 0.05$ indicates that the difference is significant). [b] Air exchange rates (AER) ≥ 5 $hr^{-1}$ were excluded from the analysis because results from the method used become unreliable.

The risk estimates for the two studied groups are presented in Figure 1. Since the data were not from a population-based sample, Figure 1 should be used only for comparison purposes within this study group, and not as risk estimates for the entire Mexican-American or White populations. Formaldehyde, p-DCB, acetaldehyde, chloroform and benzene were the largest contributors to the *CCR*. Moreover, Mexican-Americans had significantly higher estimates of cancer risk from benzene, chloroform and p-DCB than did Whites, as well as a higher *CCR*.

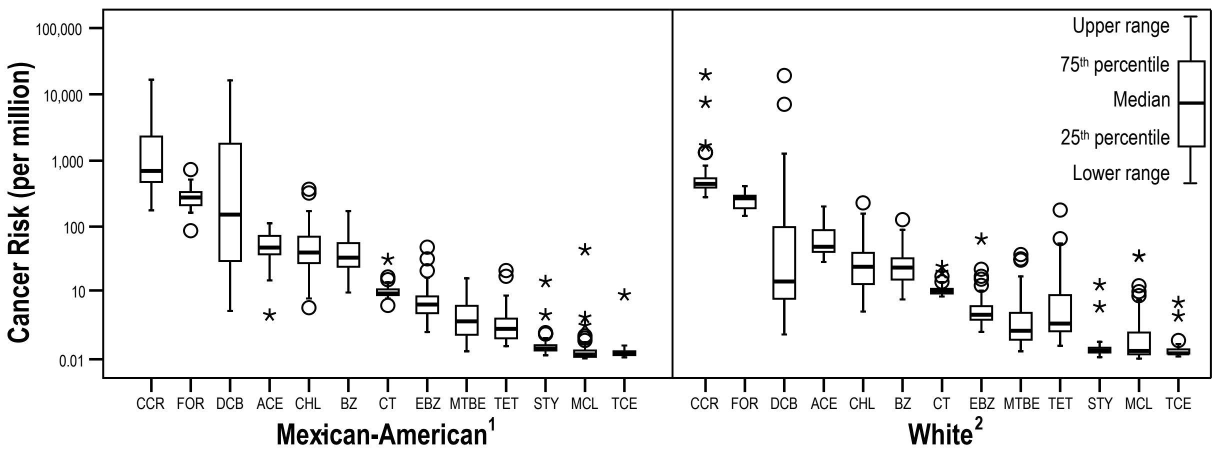


Figure 1. Cancer risks based on personal concentrations of Mexican-Americans and Whites. n: number of measurements. [1] n=50 for VOCs and 42 for carbonyls; [2] n=45 for VOCs and 37 for carbonyls. 'o' and '*' are values between 1.5 and 3, and more than 3 box lengths from the upper or lower edge of the box, respectively. Abbreviations: ACE, acetaldehyde; BZ, benzene; CCR, cumulative cancer risk; CHL, chloroform; CT, carbon tetrachloride; DCB, p-dichlorobenzene; EBZ, ethylbenzene; FOR, formaldehyde; MCL, methylene chloride; MTBE, methyl tert-butyl ether; STY, styrene; TCE, trichloroethylene; TET, tetrachloroethylene.

The contribution of each HAP to the average of *CCR* tertiles, classified as low-risk (1st tertile), mid-risk (2nd tertile) and high-risk (3rd tertile), is summarized in Figure 2. The medians of *CCR* tertiles were not used because the influence of each pollutant could not be estimated from them. Formaldehyde was the largest contributor (>37%) to the low and mid-

risk levels for both ethnic groups. Furthermore, the excess cancers from formaldehyde remained relatively comparable among the risk levels (217 to 340 per million). p-DCB was the most significant contributor to the high-risk group, accounting for 90% and 83% of the excess cancers for Mexican-Americans and Whites, respectively. The *CCR* in the high-risk level for Mexican-Americans (5834 excess cancers per million) was twice that for Whites.
The medians of *CR* tertiles for formaldehyde and p-DCB (Figure 3) are presented because the previous analysis did not address their skewed distribution. Similar excess cancers were found in all *CR* tertiles for formaldehyde for both ethnic groups (178 to 377 per million). The third tertile for p-DCB was 253 excess cancers per million among Whites. The comparable median risk for Mexican-Americans was more than 15 times higher (3925 per million).

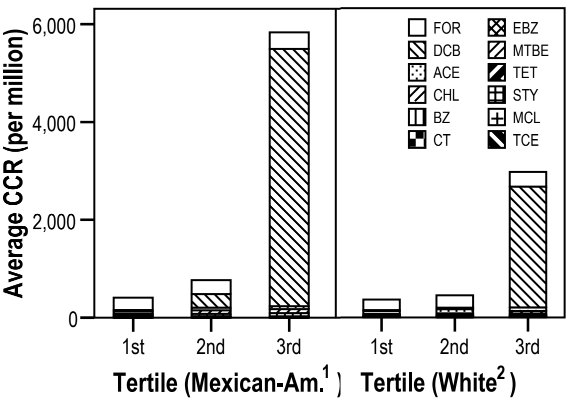


Figure 2. Average of cumulative cancer risk tertiles for Mexican-Am. and Whites. Every tertile shows the average contribution of each HAP. n: sets of measurements for which all species were available. [1] n=42; [2] n=37. Abbreviations are as given in Figure 1.

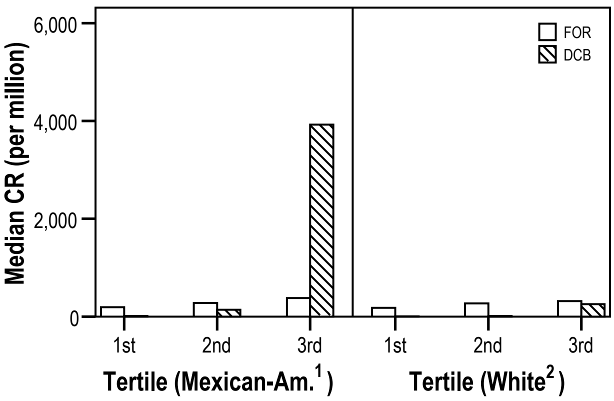


Figure 3. Median of cancer risk tertiles for formaldehyde and p-dichlorobenzene for Mexican-Am. and Whites. n: sets of measurements for which all species were available. [1] n=42; [2] n=37. Abbreviations are as given in Figure 1.

Possible sources of HAPs were evaluated by assessing the relationship between personal concentrations and both indoor and outdoor concentrations. The median personal air concentrations ($P_{med}$) of the five compounds that were estimated to have the largest effect on the *CCR* – formaldehyde, acetaldehyde, benzene, chloroform and p-DCB – are presented in Figure 4. Non-parametric analyses showed that the $P_{med}$ of benzene, chloroform and p-DCB were higher for Mexican-Americans than Whites. The distribution of ratios of personal to indoor (P/I) and personal to outdoor (P/O) levels, and their respective $R^2$ (i.e., from linear regressions with P as the dependent variable) are also shown in Figure 4. For both ethnic groups, indoor concentrations of benzene, chloroform and p-DCB ($R^2 \geq 0.92$), and to a lesser extent, formaldehyde ($R^2=0.63$ and 0.64), appeared to be good predictors of personal concentrations. This was also the case for acetaldehyde among the White participants ($R^2=0.80$). Outdoor levels of formaldehyde, acetaldehyde, chloroform and p-DCB were not adequate predictors of personal levels with $R^2<0.03$. Taken together, these observations imply that indoor concentrations play a more important role as contributors to personal exposures compared to outdoor concentrations for both ethnic groups.

## DISCUSSION

From the subset of VOCs and carbonyls included in RIOPA-Texas, formaldehyde, acetaldehyde, benzene, chloroform and p-DCB were identified as the most important contributors to excess cancers among the Mexican-American and White participants. With the possible exception of benzene, these HAPs appear to originate primarily from indoor residential sources. Mexican-Americans had higher median personal concentrations and corresponding estimated cancer risks than Whites for benzene, chloroform and p-DCB. Furthermore, Mexican-Americans also had higher overall cumulative cancer risks.

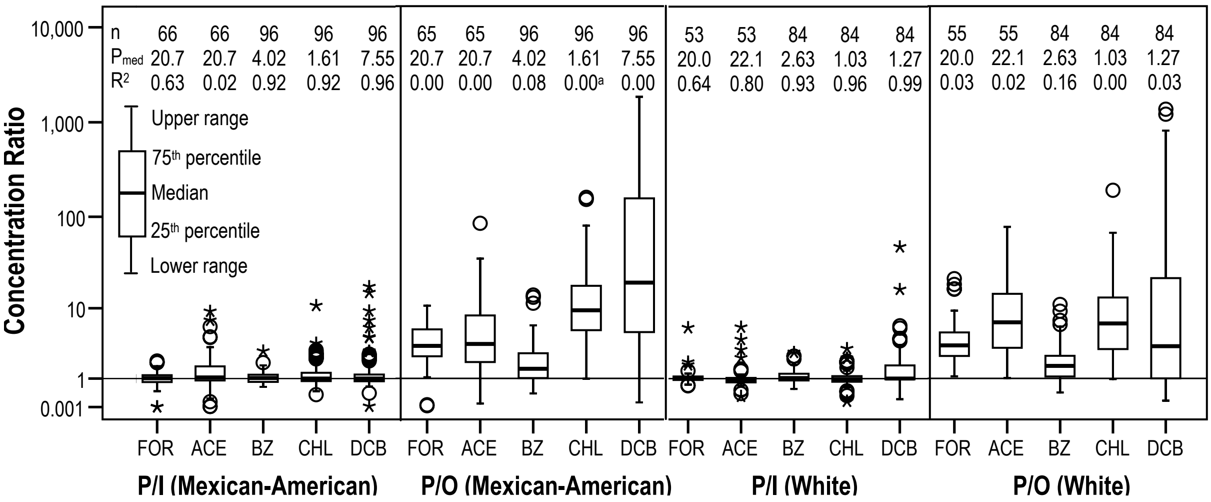


Figure 4. Ratio of personal to indoor (P/I) and personal to outdoor (P/O) concentrations of HAPs for Mexican-Americans and Whites. n: number of measurements, $P_{med}$: median personal concentration ($\mu g/m^3$), $R^2$: Coeff. of Determination for the regressions. See Figure 1 for definitions of box plots and abbreviations. [a] One outdoor extreme value was not included.

Sources of formaldehyde are ubiquitous in indoor environments, the most prevalent being pressed-wood materials, which are commonly used in house construction and furniture (Kelly et al., 1999). Indoor concentrations of formaldehyde were similar in Mexican-American and White households despite differences in house volume. A possible explanation is that the effect of larger AER in Mexican-American homes could have been offset by their smaller volumes. However, Liu et al. (2006) estimated indoor carbonyl source strengths for all the homes that participated in RIOPA, and concluded that changes in AER had the least effect on indoor concentrations, while the carbonyl emission rate and home volume had the largest impact. Moreover, Park and Ikeda (2006) determined that new homes made of wood framing reached steady-state levels of formaldehyde that were similar to those from older homes after about three years. Consequently, it is possible that cancer risks associated with formaldehyde are relatively similar among those who live in older homes, and proposed actions to reduce their indoor levels through increased ventilation may not be effective.

Mexican-Americans had significantly higher $P_{med}$ and cancer risks from benzene than Whites. Primary sources of benzene include smoking, auto exhaust or gasoline vapor emissions, and industries such as petrochemical plants (Wallace, 1996). Proximity to mobile sources and, in particular, parked gasoline-fueled vehicles, could have been one of the important differences between the two studied groups. A larger percentage of Mexican-Americans (88%) parked their cars next to their houses than did Whites (59%) during the study. Batterman et al. (2007) determined that emissions from vehicles that are in attached garages constitute a major source of benzene indoors. It is possible that cars parked in carports that are next to windows and doors could also result in some infiltration of auto exhaust or gasoline vapor emissions.

Chloroform is another HAP that appears to have a higher impact on Mexican-Americans. Adgate et al. (2004) also found that Hispanic children were exposed to elevated concentrations of this pollutant. The main indoor source of chloroform is volatilization from chlorinated tap water. Inhalation exposure from this source occurs during baths and showers, and from use of dishwashers and clothes washers. However, it was determined from the RIOPA questionnaires that more White participants engaged in some of these activities than did Mexican-Americans. Chloroform can also originate from household cleaning products that contain chlorine bleach. This source appears to be important for Mexican-Americans who reported more frequent use of bleach as a cleaning agent than did Whites. Adgate et al. (2004) also associated elevated concentrations of chloroform with household cleaner use.

p-DCB was the main contributor to the difference in *CCR* between Mexican-Americans and Whites. This finding is in agreement with the SHIELD (Adgate et al., 2004) and TEACH (Sax et al., 2006) studies, which measured high personal concentrations of p-DCB among Hispanics. Sources of p-DCB include solid toilet bowl deodorizers, air fresheners, and moth cakes. The RIOPA surveys asked about the use of the last two products, from which it was determined that they were more prevalent among Whites than Mexican-Americans. Future exposure studies should include an assessment of the use of solid toilet bowl deodorizers among ethnic groups given that they can constitute a significant health risk (Aronson et al. 2007). A potential solution to this problem has been implemented in California, where solid deodorizers that contain p-DCB have been banned (California Air Resources Board 2004).

Although cancer risk assessments were a useful tool for placing into context the measured personal concentrations from RIOPA-Texas, there are limitations that should be considered. The *CCR* estimates only included 12 HAPs; however, there are others that could also be important contributors. Furthermore, the derivation of the cancer potency factors include uncertainties such as extrapolations from studies involving animals and high doses, and use of occupational studies where exposures are higher and the subjects do not represent the population at large. Finally, the excess cancer risks are estimates based on a population of a million individuals who are exposed to a given level, so the risk estimates need to be placed in the context of the actual fraction of the population experiencing such exposures.

## CONCLUSIONS

Results from this study suggest that there were significant differences in personal exposure between the Mexican-Americans and Whites who participated in RIOPA-Texas. When compared to the White population, Mexican-Americans had higher median personal concentrations of benzene, chloroform and p-DCB; cancer risk estimates associated with these HAPs; and cumulative cancer risks. The results also show that for both ethnic groups, indoor concentrations played a dominant role in determining personal exposures to the HAPs posing the highest cancer risks, compared to outdoor concentrations. Thus the impact of indoor sources on exposures needs to be considered in policies directed at reducing risk from exposures to HAPs.

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