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Original Article

Organ toxicity from benzene exposure among elderly subjects after a flaring disaster at the BP refinery plant in Texas City

Mark A. D'Andrea[1] and *G. Kesava Reddy[1]

[1]University Cancer and Diagnostic Centers, Houston, TX, USA

***Correspondence**
G. Kesava Reddy, PhD, MHA
University Cancer and Diagnostic Centers, 12811 Beamer Road, Houston, TX 77089
Email: kreddy_usa@yahoo.com

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ABSTRACT

Objectives: To evaluate the health risks associated with benzene exposure in elderly subjects following a flaring disaster at the BP refinery in Texas City, Texas.

Methods: Elderly subjects aged 60 years and older who had been exposed and unexposed to benzene were included. We reviewed medical charts and compared measures of white blood cells (WBC), platelets, hemoglobin, hematocrit, blood urea nitrogen (BUN), creatinine, alkaline phosphatase (ALP), aspartate amino transferase (AST), and alanine amino transferase (ALT) in exposed and unexposed elderly subjects.

Results: Records from 294 elderly subjects (benzene exposed, n=216 and unexposed, n=78) were reviewed. Benzene exposed subjects had significantly higher levels of WBC (X 103 per µL) (7.7±1.9 versus 6.3±1.5, P=0.0000) and platelet (X 103 per µL) counts (256.8 ± 51.6 versus 237.9 ± 41.9, P=0.0104) compared with the unexposed subjects. Serum creatinine levels (mg/dL) were also significantly increased in the exposed group compared with the unexposed group (1.1 ± 0.4 versus 0.9±0.2, P=0.000). Serum levels of ALP (IU/L) were significantly elevated in the exposed subjects compared with the unexposed subjects (87.5 ± 23.6 versus 72.5 ± 17.8, P=0.000). Similarly, benzene exposed subjects had significantly higher levels of AST (24.8 ± 6.2 versus 19.2 ± 5.1, IU/L, P=0.000) and ALT (24.2 ± 8.6 versus 19.1 ± 4.8, IU/L, P=0.000) compared with those unexposed to benzene.

Conclusions: Benzene exposure resulted in significant alterations in hematological and hepatic profiles among elderly subjects.

INTRODUCTION

Petroleum refining industries are a major source of production of toxic chemicals such as benzene, toluene, and other volatile organic compounds in the environment.[1] Benzene emission occurs most commonly during petroleum refinery operations.[2] As a volatile organic compound, benzene is one of the major environmental contributors to air pollutants. It is found as a contaminant from both natural processes and human activities.[3,4] Environmental contamination of benzene originates mainly from its industrial uses through improper discharge into the air. In addition, benzene is a commercially important intermediate chemical and used widely in the synthesis of various polymers, resins, and synthetic fibers. As a toxic pollutant, benzene is associated with significant health risks in communities surrounding petroleum refineries due to the increased probability of their exposure.[5]

It is well established that human exposure to benzene is associated with increased risks of developing carcinogenesis, specifically, leukemia, lymphoma, and aplastic anemia.[6,7,8,9,10] In addition, benzene exposure can cause a wide range of non-cancerous deleterious effects leading to impairment of the hematological, hepatic, renal, cardiovascular, neurological, and immune functions.[11,12,13,14,15,16] Moreover, benzene exposure is associated with several adverse respiratory effects including pulmonary edema, acute granular tracheitis, laryngitis, bronchitis, and massive hemorrhaging.[17,18] Benzene exposure can also affect both B-cell and T-cell proliferation, reduce host resistance to infections and produce chromosomal aberrations.[19]

The adverse health effects of benzene exposure in adults have been well-documented and somewhat less in pediatric populations but not in elderly populations. Earlier studies have demonstrated that the elderly subjects are more susceptible to the effects of environmental pollutants than the young adult population.[20,21] The increased susceptibility of elderly individuals to environmental pollutants could be due to the normal and pathological aging and related processes. Normal aging in the elderly is associated with a progressive and inexorable loss of vital organ function leading to increased vulnerability to disease, frailty, and disability. In general, aging is accompanied by a gradual decline in the immune defense and respiratory

functions leading to respiratory infections.[22,23,24] Moreover, as the biologic capacity gradually declines with normal aging, these processes are exacerbated in pathologic aging. This decline can lead to compromised pharmacokinetic and pharmacodynamic responses to environmental pollutants. Furthermore, toxic exposure rates, absorption, metabolism, excretion, and tissue vulnerability all seems to be age related[25] and thus, elderly individuals are more susceptible to the effects of environmental toxic pollutants. Thus, a better understanding of the health consequences faced by elderly populations following their exposure to toxic chemicals, particularly exposure to carcinogenic chemicals such as benzene is warranted.

In Texas City, Texas, a 2010 flaring disaster at the BP refinery facility lasted 40 days and led to the release of over 500,000 pounds of toxic chemicals, including over 17,000 pounds of benzene into the skies.[26,27,28] Environmentally, this flaring disaster polluted the air with the toxic emission, especially benzene and threatened the health of local communities living in close proximity to the BP refinery facility. To better understand more thoroughly the potential adverse health effects of the ambient benzene exposure resulting from the BP flaring disaster, we are conducting a series of studies by examining hematological and hepatic functions in children, adults, and elderly population following their exposure to benzene.[29,30,31,32] The findings of these studies demonstrated that benzene exposure from the BP flaring disaster significantly altered the hematological and hepatic functions in the exposed populations. In this study, we investigated the health consequences of benzene exposure in elderly subjects after being exposed to the flaring disaster at the BP refinery facility.

SUBJECTS AND METHODS

Subjects

This retrospective study was approved by an Institutional Review Board. The details of the subjects' selection and the procedures employed for the clinical and laboratory evaluations were reported previously.[29,30,31,32,33,34] Briefly, using medical charts, subjects who underwent clinical as well as laboratory evaluations between June 2010 and October 2012 were included. The residential areas affected by the flaring disaster of BP refinery facility were initially identified and the subjects exposed to the emissions were selected from the affected areas of the surrounding communities of Texas City, Texas (Figure 1). The subjects self-reported

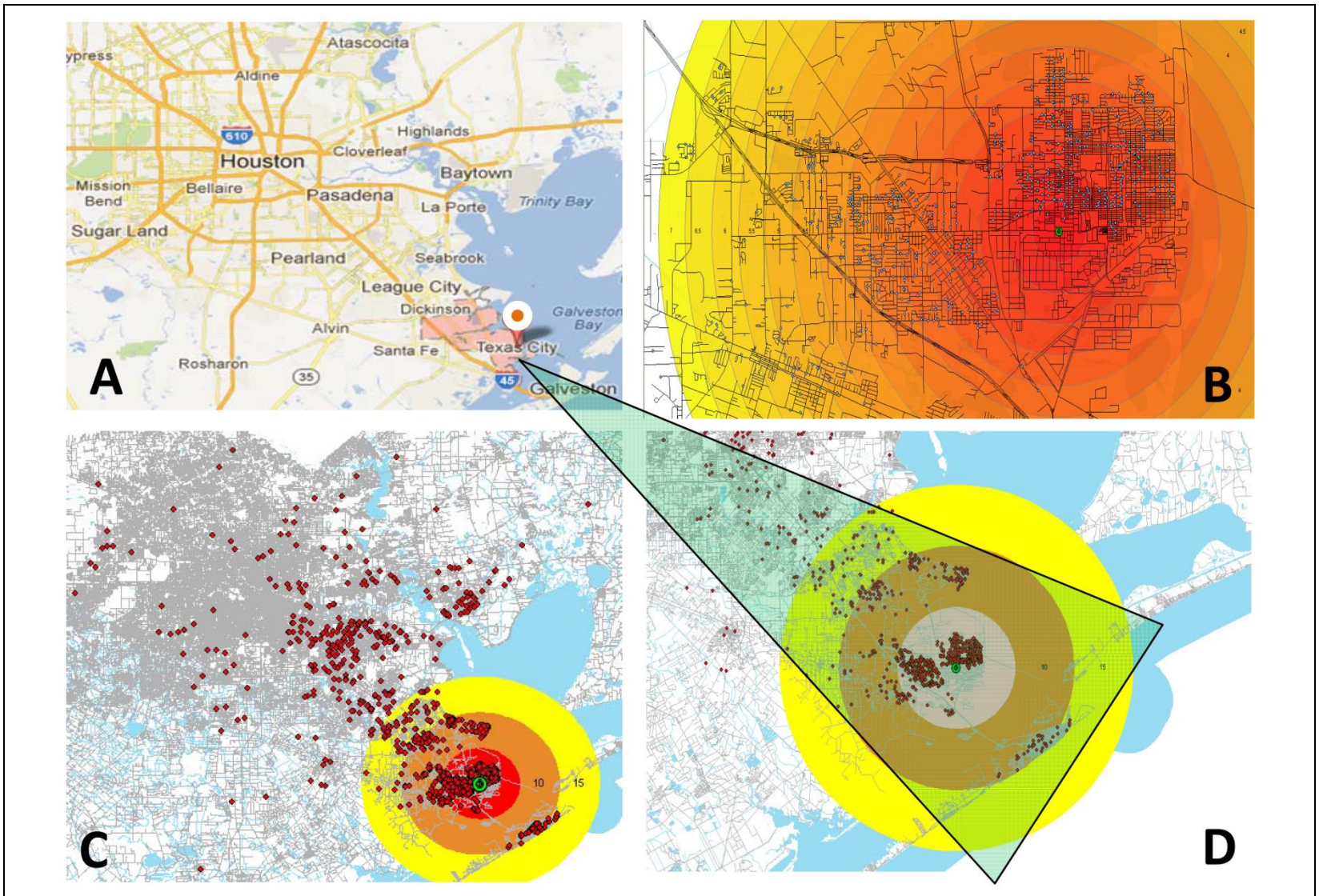

Figure 1. Map showing the location of the disaster of BP refinery facility in the northern parts of the Texas City. **A.** Location of Texas City, Texas. **B.** Depicted intensity of benzene exposure from BP incident surrounding neighborhoods of Texas City, Texas. The red, orange, and yellow colors depict the higher (red) to reduced (orange) to low (yellow) intensity of benzene exposure. **C.** Scattered dots represent the location/address of the study participants who were exposed to benzene following a flaring incident at the BP refinery and surrounding areas. **D.** A closer look at the affected area by the benzene exposure and the address of the study participants (scattered dots).

exposure to benzene following the flaring disaster from April 6, 2010 through May 16, 2010. Unexposed subjects were drawn from primary care clinics located approximately 30 – 50 miles away from the BP refinery plant. Unexposed subjects were individuals who visited the clinics for a routine wellness checkup. They were selected randomly by their primary care physicians. Only subjects (exposed and unexposed to benzene) aged 60 years or older were included in this study. Demographic and clinical laboratory data were reviewed and gathered for both benzene exposed and unexposed subjects and analyzed. The study was conducted according to the ethical principles of the Declaration of Helsinki. To comply with the Health Insurance Portability and Accountability Act (HIPAA), confidentiality of information was secured by utilizing text encryption, password protection and limited personnel involvement.

Chart Review and Data Gathering

Study investigators reviewed the medical charts of the benzene exposed and unexposed subjects. Clinical data including white blood cell (WBC) counts, platelet counts, hemoglobin, hematocrit, blood urea nitrogen (BUN), creatinine, alkaline phosphatase (ALP), aspartate amino transferase (AST), and alanine amino transferase (ALT) levels were evaluated and compared between the exposed and unexposed groups. All laboratory tests were performed by an accredited laboratory facility (LabCorp, Laboratory Corporation of America, Houston, TX).

Statistical Analyses

Data from the laboratory examinations in this study was systematically collected from the subjects' medical charts and subjected to statistical analysis. Descriptive statistics were employed to assess patient demographics which included means and standard deviations for each group. Variables included were WBC, platelets, hemoglobin, hematocrit, creatinine, BUN, ALP, AST, and ALT. Student's t-test was used to assess the differences between the benzene exposed and unexposed groups. The significance level was predetermined at an alpha level of 0.05.

RESULTS

A total of 294 elderly subjects aged 60 years or older were included in this study. Of the 294 subjects, 78 were unexposed and 216 were exposed to benzene. The subjects' demographics are shown in Table 1. The mean age of the unexposed and benzene exposed subjects was 69 and 68.7 years, respectively. Among unexposed subjects (n=78), there were 41% (n=32) male and 59% (n = 46) female subjects. In the benzene exposed group (n=216), there were 55% (n=119) male and 45% (n=97) female subjects. Of the 78 unexposed subjects, 48 (62%) were less than 70 years and 30 (38%) were over 70 years. In the benzene exposed group (n=216), 128 (59%) were less than 70 years and 88 (41%) were over 70 years. Nonsmoking subjects accounted for 86 % and 60% in the unexposed and benzene exposed groups, respectively. The median time from the time of disaster to the time of laboratory testing was 128 (range, 75-472) days.

Table 1. Demographics of the study subjects

Demographics	Unexposed	Exposed
Total subjects	78 (100%)	216 (100%)
Mean age	69.0 years	68.7 years
Gender		
Male	32 (41%)	119 (55%)
Female	46 (59%)	97 (45%)
Age group, years		
< 70	48 (62%)	128 (59%)
≥ 70	30 (38%)	88 (41%)
Smoking status		
Nonsmokers	63 (86%)	130 (60%)
Smokers	15 (14%)	86 (40%)
Median time from the time of disaster to the time of laboratory testing (range), days	--	128 (75-472)

The results presented in Table 2 show the differences in the hematologic and hepatic indices between the unexposed and exposed elderly subjects to benzene. The elderly subjects who were exposed to benzene experienced significantly increased mean WBC counts (X 10^3 per µL) compared with the unexposed subjects (7.7 ± 1.9 versus 6.3 ± 1.5, P=0.000). Similarly, the mean platelet counts (X 10^3 per µL) in the benzene exposed group were significantly higher when compared with the unexposed group (256.8 ± 51.6 versus 237.9 ± 41.9, P=0.0104). The mean BUN levels (mg/dL) were also significantly increased in the benzene exposed group compared with the unexposed group (15.4 ± 2.9 versus 17.8 ± 3.8, P=0.0026). The mean serum creatinine levels (mg/dL) were significantly increased in the benzene exposed group compared with the unexposed group (1.1 ± 0.4 versus 0.9 ± 0.2, P=0.000). However, no significant differences were observed in the mean hemoglobin (g/dL) and hematocrit (%) levels between the exposed and unexposed groups.

The mean serum ALP (IU/L) levels were higher in subjects exposed to benzene compared with unexposed elderly subjects (87.5 ± 23.6 versus 72.5 ± 17.8, P=0.000).

Table 2. Comparison of hematological and hepatic indices between unexposed and exposed elderly subjects to benzene

Variable	Unexposed (N = 78)	Exposed (N = 216)	P Value
WBC (X 10^3 per µL)	6.3 ± 1.5	7.7 ± 1.9	0.0000*
Platelets (X 10^3 per µL)	237.9 ± 41.9	256.8 ± 51.6	0.0104**
Hemoglobin (g per dL)	13.8 ± 1.2	13.8 ± 1.8	0.4552$^{\psi}$
Hematocrit (%)	41.5 ± 3.2	41.7 ± 4.5	0.3493$^{\psi}$
BUN (mg per dL)	15.4 ± 2.9	17.8 ± 3.8	0.0026*
Creatinine (mg per dL)	0.9 ± 0.2	1.1 ± 0.4	0.0000*
ALP (IU per L)	72.5 ± 17.8	87.5 ± 23.6	0.0000*
AST (IU per L)	19.2 ± 5.1	24.8 ± 6.2	0.0005*
ALT (IU per L)	19.1 ± 4.8	24.2 ± 8.6	0.0003*

*P=0.001; ψ= did not reach statistical significance
WBC, white blood cells; BUN, blood urea nitrogen; ALP, alkaline phosphatase; AST, aspartate amino transferase; ALT, alanine amino transferase.

Table 3. Comparison of hematological and hepatic indices between unexposed and benzene exposed elderly subjects according to their gender

Variable	Gender	Unexposed$^{\delta}$	Benzene Exposed$^{\beta}$	P Value
WBC (X 10^3 per μL)	Male	6.4 ± 1.5	7.6 ± 2.0	0.0012*
	Female	6.3 ± 1.4	7.9 ± 1.8	0.0000*
Platelets (X 10^3 per μL)	Male	221.6 ± 53.9	255.6 ± 66.7	0.0044*
	Female	242.8 ± 40.3	272.7 ± 55.0	0.0007*
Hemoglobin (g per dL)	Male	14.7 ± 1.0	14.4 ± 1.7	0.1640$^{\Psi}$
	Female	13.2 ± 0.8	13.1 ± 1.7	0.2943$^{\Psi}$
Hematocrit (%)	Male	43.8 ± 2.7	43.0 ± 4.6	0.1872$^{\Psi}$
	Female	39.9 ± 2.5	39.7 ± 4.7	0.3932$^{\Psi}$
BUN (mg per dL)	Male	15.6 ± 3.3	16.8 ± 3.9	0.1760$^{\Psi}$
	Female	15.3 ± 4.3	18.5 ± 5.9	0.0220$^{\Psi}$
Creatinine (mg per dL)	Male	0.9 ± 0.2	1.1 ± 0.3	0.0008*
	Female	0.8 ± 0.1	1.0 ± 0.3	0.0005*
ALP (IU per L)	Male	68.2 ± 7.8	82.9 ± 9.3	0.0003*
	Female	72.9 ± 7.8	88.4 ± 9.3	0.0003*
AST (IU per L)	Male	20.7 ± 4.9	26.4 ± 7.1	0.0064*
	Female	17.9 ± 4.7	21.7 ± 6.7	0.0031*
ALT (IU per L)	Male	20.3 ± 8.2	29.2 ± 12.6	0.0010*
	Female	16.5 ± 3.2	20.7 ± 4.6	0.0061*

*Differences between benzene exposed and unexposed groups are significant. $^{\Psi}$ Did not reach statistical significance.
$^{\delta}$Male unexposed: n=32; $^{\delta}$Female unexposed: n=46; $^{\beta}$Male exposed: n=119; $^{\beta}$Female exposed: n=97.
WBC, white blood cells; BUN, blood urea nitrogen; ALP, alkaline phosphatase; AST, aspartate amino transferase; ALT, alanine amino transferase.

Table 4. Comparison of hematologic and hepatic indices by age group between unexposed and exposed elderly subjects to benzene

Variable	Age Group	Unexposed$^{\delta}$	Benzene Exposed$^{\beta}$	P Value
WBC (X 10^3 per μL)	< 70 years	6.3 ± 1.5	7.6 ± 1.6	0.0000*
	≥ 70 years	6.2 ± 1.4	7.9 ± 2.2	0.0000*
Platelets (X 10^3 per μL)	< 70 years	234.1 ± 50.7	261.3 ± 57.8	0.0046*
	≥ 70 years	240.4 ± 51.3	272.9 ± 63.8	0.0064**
Hemoglobin (g per dL)	< 70 years	14.0 ± 1.1	14.2 ± 1.7	0.2116$^{\Psi}$
	≥ 70 years	13.6 ± 1.2	13.3 ± 1.6	0.1814$^{\Psi}$
Hematocrit (%)	< 70 years	41. 8 ± 3.1	42.4 ± 4.4	0.1939$^{\Psi}$
	≥ 70 years	41.0 ± 3.3	40.3 ± 5.5	0.2429$^{\Psi}$
BUN (mg per dL)	< 70 years	15.3 ± 3.9	17.3 ± 4.6	0.0437**
	≥ 70 years	15.6 ± 4.0	17.8 ± 4.8	0.1094**
Creatinine (mg per dL)	< 70 years	0.9 ± 0.2	1.1 ± 0.2	0.0488**
	≥ 70 years	0.9 ± 0.2	1.1 ± 0.3	0.0006*
ALP (IU per L)	< 70 years	71.8 ± 12.9	86.5 ± 16.2	0.0001*
	≥ 70 years	72.0 ± 13.8	86.1 ± 18.6	0.0031*
AST (IU per L)	< 70 years	19.1 ± 4.5	24.7 ± 6.3	0.0081*
	≥ 70 years	18.9 ± 5.1	23.1 ± 6.2	0.0164*
ALT (IU per L)	< 70 years	18.5 ± 6.8	26.8 ± 8.9	0.0000*
	≥ 70 years	17.3 ± 5.87	23.7 ± 7.6	0.0024*

**P=0.05; *P=0.001; $^{\Psi}$ Did not reach statistical significance.
$^{\delta}$Unexposed < 70 years: n= 48; $^{\delta}$Unexposed > 70 years: n=30; $^{\beta}$Exposed < 70 years: n=128; $^{\beta}$Exposed > 70 years: n=88.
WBC, white blood cells; BUN, blood urea nitrogen; ALP, alkaline phosphatase; AST, aspartate amino transferase; ALT, alanine amino transferase.

Mean serum AST (IU/L) levels were significantly higher in the benzene exposed subjects compared with the unexposed subjects (24.8 ± 6.2 versus 19.2 ± 5.1, P=0.005). The mean serum ALT (IU/L) levels were increased significantly in the benzene exposed group compared with the unexposed group (24.2 ± 8.6 versus 19.1 ± 4.8, P=0.0003).

The findings in Table 3 show the differences in the hematologic and hepatic markers between the benzene exposed and unexposed elderly subjects according to their gender. The mean WBC counts (X 10^3 per μL) were significantly increased in male (7.6 ± 2.0 versus 6.4 ± 1.5, P=0.0012) and female (7.9 ± 1.8 versus 6.3 ± 1.4, P=0.0000)

Table 5. Comparison of hematologic and hepatic indices by smoking status between unexposed and exposed elderly subjects to benzene

Variable	Smoking Status	Unexposed[δ]	Benzene Exposed[β]	P Value
WBC (X 10^3 per μL)	Nonsmoking	6.3 ± 1.5	7.7 ± 1.8	0.0000*
	Smoking	6.2 ± 1.6	7.9 ± 1.9	0.0469**
Platelets (X 10^3 per μL)	Nonsmoking	237.7 ± 53.4	250.7 ± 53.7	0.0495**
	Smoking	228.8 ± 16.5	270.9 ± 45.8	0.0209**
Hemoglobin (g per dL)	Nonsmoking	13.8 ± 1.2	13.5 ± 1.8	0.1516[ψ]
	Smoking	13.3 ± 1.3	13.8 ± 1.7	0.4109[ψ]
Hematocrit (%)	Nonsmoking	41. 6 ± 3.2	40.7 ± 5.0	0.1798[ψ]
	Smoking	40.7 ± 3.4	41.6 ± 4.9	0.3536[ψ]
BUN (mg per dL)	Nonsmoking	15.6 ± 3.9	19.0 ± 4.6	0.0013*
	Smoking	13.0 ± 3.1	17.5 ± 4.8	0.1182[ψ]
Creatinine (mg per dL)	Nonsmoking	0.9 ± 0.2	1.1 ± 0.3	0.0001*
	Smoking	0.8 ± 0.2	1.0 ± 0.3	0.0400*
ALP (IU per L)	Nonsmoking	72.3 ± 13.9	85.3 ± 17.2	0.0001*
	Smoking	66.4 ± 7.2	86.3 ± 19.6	0.0346**
AST (IU per L)	Nonsmoking	19.2 ± 4.9	23.2 ± 7.3	0.0027**
	Smoking	15.8 ± 3.3	25.2 ± 6.8	0.0548**
ALT (IU per L)	Nonsmoking	17.8 ± 6.9	23.9 ± 8.6	0.0014*
	Smoking	16.4 ± 6.0	24.6 ± 9.3	0.0373**

**P=0.05; *P=0.001; [ψ] Did not reach statistical significance.
[δ]Unexposed nonsmokers: n=63; [δ]Unexposed smokers: n=15; [β]Exposed nonsmokers: n=130; [β]Exposed smokers: n=86.
WBC, white blood cells; BUN, blood urea nitrogen; ALP, alkaline phosphatase; AST, aspartate amino transferase; ALT, alanine amino transferase.

subjects exposed to benzene compared with the unexposed subjects. Similarly, the mean platelet counts (X 10^3 per μL) were increased in male (255.6 ± 66.7 versus 221.6 ± 53.9, P=0.0044) and female (272.7 ± 55.0 versus 242.8 ± 40.3, P=0.0007) subjects exposed to benzene compared with the unexposed subjects. The mean serum creatinine levels (mg/dL) were also significantly increased in both male (1.1 ± 0.3 versus 0.9 ± 0.2, P=0.0008) and female (1.0 ± 0.3 versus 0.8 ± 0.2, P=0.0005, mg/dL) subjects exposed to benzene compared with the unexposed group. Hepatic serum enzymes such as ALP, AST and ALT were also found to be significantly elevated in benzene exposed subjects compared with those unexposed subjects regardless of their gender (P <0.05). However, the mean hemoglobin (g/dL) and hematocrit (%) levels remained similar in both male and female subjects regardless of their exposure to benzene.

To evaluate if age contributed to any observed health effects of benzene exposure, a further analysis was performed by grouping elderly subjects into two (<70 years and ≥70 years) age groups and comparing the clinical outcomes between the benzene exposed and unexposed groups. The findings in Table 4 show the differences in the hematologic and hepatic indices between exposed and unexposed elderly subjects among the two age groups. Regardless of the age group, the mean WBC and platelet counts were significantly increased in benzene exposed subjects compared with their matched unexposed subjects. Similarly, the serum levels of hepatic enzymes (ALP, AST and ALT) were increased significantly in the benzene exposed subjects compared with the unexposed subjects, irrespective of the age group. However, no significant differences were observed in the mean hemoglobin, hematocrit, and BUN levels between the unexposed and benzene exposed elderly subjects in either age-group, except for significant increases in the mean BUN levels in subjects aged <70 years in the benzene exposed group compared with the unexposed group.

The results in Table 5 indicate the differences in the hematologic and hepatic indices according to the subjects smoking status between benzene exposed and unexposed groups. The mean WBC and platelet counts were significantly increased in benzene exposed subjects compared with their matched unexposed subjects, irrespective of their smoking status. Similarly, the serum levels of hepatic enzymes (ALP, AST and ALT) were increased significantly in the benzene exposed subjects compared with the unexposed subjects, regardless of their smoking status. No significant differences were observed in the mean hemoglobin and hematocrit levels between the unexposed and benzene exposed elderly subjects irrespective of their smoking status.

DISCUSSION

In developed countries, the rapid growth in elderly populations has major implications for public health, including the need to better understand the risks associated with environmental toxic exposure. While a number of studies have assessed the health consequences of benzene

exposure in an adult population, virtually no reports exist in literature evaluating the health consequences of benzene exposure in an elderly population. It is important to recognize that the toxic effects of benzene exposure in the general population may not be representative of the effects on certain subgroups such as elderly individuals. Moreover, the elderly are at a greater risk from toxic exposures than other age groups due to their enhanced susceptibility and vulnerability. This study sought to investigate the adverse health effects of benzene exposure in elderly subjects after a prolonged toxic release from the BP flaring disaster. To the best of our knowledge, this is the first and only study of its kind that has evaluated the health consequences in an elderly population following the benzene exposure from the flaring disaster at the BP refinery plant in Texas City, Texas.

The findings of this study reveal that benzene exposure resulted in significant changes in the hematological and hepatic profiles in the elderly subjects studied. In particular, the mean WBC and platelet counts were significantly increased in those subjects exposed to benzene compared with the unexposed elderly subjects. Similarly, the BUN and creatinine levels were increased significantly in the benzene exposed group compared with the unexposed group. However, the hemoglobin and hematocrit levels remained similar between the benzene exposed subjects as compared with the unexposed subjects. Although previous studies have assessed the hematological effects of benzene exposure,[35,36] the study populations included in those studies were much younger than our study population. In a study by Liu et al[35] the mean age of the benzene exposed subjects was 47 years; whereas in our study, the mean age of the benzene exposed subjects was over 68 years. Similarly, Ray et al[36] studied the hematological effects of benzene exposure in younger adults with the mean age of 37 years. The findings of those previous studies support our study findings suggesting benzene exposure leads to hematotoxicity irrespective of the age of the affected populations.

Hemoglobin and hematocrit levels were similar among the benzene-exposed and unexposed elderly subjects. However, serum creatinine and BUN levels were significantly elevated in the benzene-exposed group. It is well established that serum creatinine levels are important indices of kidney function. Thus, these findings suggest that those elderly subjects exposed to benzene may be at an increased risk of impaired renal function. These findings are consistent with previously published studies demonstrating significantly elevated serum creatinine levels in subjects exposed to benzene or petroleum products.[37]

Benzene exposure has been shown to impact liver functions. In this study we assessed liver function enzymes such as ALP, AST and ALT in the serum of benzene exposed elderly subjects and compared them with those of unexposed elderly subjects. Assessment of liver enzyme levels in the serum is routinely used as markers for hepatic function.[38] The serum levels of ALP, AST and ALT were found to be elevated in those elderly subjects who were exposed to benzene compared with the unexposed elderly subjects. Currently, there exist no studies in the literature assessing the effect of benzene exposure on liver enzymes in elderly subjects to compare with our study findings. However, our results are similar in part with those other published studies where increased liver enzymes have been reported in younger adult subjects who were exposed to benzene or petroleum products and organic solvents.[39,40,41,42,43] The increased serum levels of these enzymes in elderly subjects could be due to the overproduction or release of enzymes from the liver cells in response to stimuli of hepatocellular injury or cell death. Nevertheless, these results suggest that elderly subjects exposed to benzene could be at an increased risk of hepatic tissue toxicity compared with those of unexposed elderly subjects.

A subgroup analysis was performed to further understand the influence of variables on benzene exposure related changes in elderly subjects. Specifically, we examined the influence of gender, age (<70 years and >70 years) and smoking on the hematological and hepatic functions in benzene exposed elderly subjects and the findings were compared with the unexposed elderly subjects. Findings from this study indicate that both the hematological and hepatic functions were significantly affected in the benzene exposed elderly subjects compared with the unexposed elderly subjects regardless of their gender, age or smoking status.

We acknowledge that this study has a number of limitations and therefore the findings should be interpreted cautiously. Importantly, this study was conducted using a cross-sectional design. A cross-sectional study design allows only for generating a hypothesis for further investigation, and not causality to be investigated. Using such a study design, it is difficult to infer causality due to the clinical outcomes were measured at one time point after an event. Thus, the causality can only be an assumption. Another important limitation of this study is the lack of baseline data prior to the benzene exposure for comparison. Since this was a retrospective study, it has several methodological limitations including the lack of information on comorbidities, occupation, alcohol use, physical activity, and differences in baseline parameters. We assume that these confounding factors are distributed similarly between benzene exposed and unexposed groups. Thus, the findings of the study should be interpreted with caution. Future studies should follow elderly subjects prospectively to detect potential long-term risks for development of carcinogenesis and other toxic effects of benzene exposure.

Nonetheless, our findings suggest that benzene exposure from the BP refinery disaster is associated with significant adverse health effects in elderly subjects. The adverse effects from benzene exposure may cause impairment not only in the hematological and hepatic functions, but other organ functions in exposed elderly subjects. Since benzene exposure is linked with an increased risk of carcinogenesis,[6,7,8,9,10] it is crucial that those elderly subjects who were exposed to benzene may have higher risk for potential long-term toxicities to their bone marrow, liver, kidney and other affected vital organs. Therefore, periodic health checkups, routine laboratory evaluations including blood, cardiac, neurologic, pulmonary, and other organ function tests may be performed to monitor the long-term health consequences of their benzene exposure.

Longitudinal and mechanistic studies are necessary to further explore the importance and nature of the adverse effects of benzene exposure in affected populations. Furthermore, the adverse effects of benzene exposure appear to be long-lasting, therefore close follow-up studies are required to determine its long-term health impact in the affected elderly populations.

CONCLUSIONS

The findings of this study reveal that benzene exposure has a potential to alter hematological, hepatic, and other organ functions in elderly subjects. Specifically, the hematological alterations observed were increased WBC counts, platelet counts, and BUN in the benzene exposed elderly subjects compared with unexposed elderly subjects. Hepatic alterations noted were increased levels of ALP, AST, and ALT in the serum of the benzene exposed elderly subjects indicating hepatic injury in these exposed subjects. Renal function also was affected by the benzene exposure in these elderly subjects. As this is a retrospective study the observed findings could be influenced by compounding factors that are inherent to the study design. Since the procedures used in this study did not follow a predefined scheme, this may have biased the interpretation of the results. Nonetheless, these findings reveal potential health effects of benzene exposure in elderly subjects. Additional studies are underway to determine the potential health effects of the benzene exposure from the flaring disaster at the BP refinery facility in the affected communities of Texas City, Texas.

CONFLICT OF INTEREST STATEMENT

No conflict of interest was declared among authors.

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