OCCUPATIONAL EXPOSURE TO BTEX COMPOUNDS OF WORKERS IN CAR PARKINGS AND GASOLINE STATIONS IN ATHENS

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SUMMARY

The occupational exposure of workers in car parking stations and gasoline service stations to benzene, toluene, m+p-xylenes, o-xylene and ethylbenzene (BTEX fraction) was assessed from January to June 2001. The exposure concentration levels were determined using passive samplers in the breathing zone of workers and at steady points in the breathing level. For two enclosed car parkings the mean concentration values of benzene, toluene and Σ[BTEX] were 366, 374 and 1246 μg m^{-3} correspondingly, depending on the car density and on the ventilation rate of the building. For the gasoline service stations the corresponding values were 1731, 1995 and 5352 μg m^{-3} depending on the amount of fuels used during the car refueling. In almost all cases the benzene concentrations were higher than air quality limits set by NIOSH and ACGIH.

Introduction

Vehicle induced and gasoline vapor emissions constitute the main sources of air pollutants in underground parking facilities and gasoline service stations respectively. Volatile organic compounds (VOC), associated with the exposure to motor vehicle exhaust and / or gasoline vapor emissions, are pollutants of great concern due to their toxicity [1-14]. In garages and gasoline stations facilities the VOC concentration levels are quite elevated due to the vehicle – induced emissions and evaporation losses during refueling the automobiles. Air quality in such working places depends on several factors such as vehicular characteristics (age, emission control technology, fuel quality etc) and factors related to the characteristics of facilities (indoor or open facilities, ventilation systems, size and maintenance) [15].

In this study the VOC exposure of workers in enclosed garages and open air gasoline service stations was evaluated. The BTEX compounds were determined by means of passive samplers, placed both on workers and stationary points and gas chromatography. The results recorded by this

work, were compared with limits of exposure to BTEX proposed or established by several organizations.

Materials and method

The BTEX sampling was carried out in two enclosed garages and two open air gasoline service stations, located on roads close to Athens center. During exposure, the concentrations of BTEX compounds in ambient air were monitored continuously for at least 6 h, with personal diffusive samplers (SKC 575-001) placed at stationary points at the height of breathing zone or attached to the clothing within the respiratory zone of the workers [16]. Totally 40 samples were collected. Diffusive samplers were desorbed with 2 ml of carbon disulfide. After being shaked for 1 h, 5 μl of the extract was injected into a Perkin Elmer Sigma 2000 gas chromatograph equipped with a split-spitless injector and a flame ionization detector.

Results

Car parking stations

Table 1 summarizes the BTEX concentrations from workers and stationary points at the height of respiratory zone, obtained from two enclosed garages. The car parking stations recorded the highest indoor air concentration for toluene with mean value 374 ± 133 μg m^{-3} and the lowest one for ethylbenzene with mean value 102 ± 35 μg m^{-3}.

As it is shown in Table 2 the BTEX concentration values in the different floors of the underground car parking station (C1) were related to the number of the cars parked per floor. Higher concentration values were determined in air samplers taken from the first and second underground floor of car parking station C1, where the density of cars / 1000 m^3 were 13,4 and 13,7, respectively. At the third floor the density was 7,2.

The underground parking garage C1, recorded higher values of BTEX compounds than the above-ground one, although it appears lower density of cars (11 cars/1000 m^3) than the other one (18,5 cars/1000 m^3). This can be explained by the ventilation differences between the two types of parking garages. Although mechanical ventilation system was operating during work time in the underground parking against physical ventilation of the above-ground one, it can be assumed that this system was not sufficient to prevent a build-up of the BTEX pollutants emitted from vehicles driving in and out.

Table 1. Mean and standard deviation (s), median of BTEX concentration values (μg m^{-3}) in personal air of workers and air samples of stationary points 1.5 m above the ground, obtained from enclosed garages.

VOC	C1 (underground) (09:00 – 15:00)		C2 (super terrestrial) (08:30 – 15:30)		C1 + C2	
	Stationary points (n=13)		Workers (n=12)		Points and workers (n=25)	
	Mean ± s	Range	***Mean ± s***	***Range***	Mean ± s	Range
Benzene, μg m^{-3}	400 ± 101 (405)[α]	262 - 569	329 ± 131 (330)	118 - 574	366 ± 119 (350)	118 - 574
Toluene, μg m^{-3}	383 ± 125 (338)	215 - 542	365 ± 146 (348)	191 - 683	**374 ± 133** (338)	**191 - 683**
Ethylbenzene, μg m^{-3}	103 ± 33 (98)	56 - 164	101 ± 39 (92)	55 - 190	**102 ± 35** (93)	**55 - 190**
m+p -xylenes, μg m^{-3}	276 ± 81 (257)	169 - 442	283 ± 136 (245)	144 - 625	279 ± 108 (250)	144 - 625
o- xylene, (μg m^{-3})	110 ± 25 (104)	73 - 152	140 ± 54 (120)	92 - 287	124 ± 43 (110)	73 - 287
Σ $[BTEX]_1^6$ μg m^{-3}	1272 ± 268 (1269)	894 -1849	1218 ± 489 (1118)	658 - 2360	1246 ± 383 (1166)	658 - 2360

[α]Values in parenthesis are the median concentrations

Table 2. BTEX concentrations per underground floor for parking station C1.

Parameter	**Floor 1**	**Floor 2**	**Floor 3**
Density of parked cars (cars / 1000 m^3)	13.7	13.7	7.2
Number of samples	5	5	3
[Benzene], μg m^{-3}	406	418	360
[Toluene] , μg m^{-3}	458	390	249
[Ethylbenzene] , μg m^{-3}	77.7	129	100
[m+p-xylene] , μg m^{-3}	265	323	216
[o-xylene] , μg m^{-3}	112	117	95.4
Σ[BTEX] , μg m^{-3}	1318	1377	1020

Gasoline service stations

In Table 3 the concentrations of BTEX compounds of air samples obtained from two open air gasoline service stations are given. The air samples are classified into personal, pumps and pump inlet air samples and the data of these three groups were compared.

In both gasoline service stations, the mean concentrations of BTEX compounds were 3 times higher in personal air than air samples collected 1 m above the pumps. In the gasoline service stations, in terms of personal and pump air, toluene was the most abundant with mean values and standard deviations, 1995 ± 1860 and 526 ± 339 mg m^{-3} , respectively.

Comparing the mean values of BTEX compounds in gasoline service station G1, when air samples were taken in two different shifts, it was observed that the afternoon levels of BTEX were significantly higher (three times) than the morning ones, due to the higher volume of gasoline sold and the windless conditions. During the afternoon shift 6000 l of gasoline sold, against 4500 l in the morning shift. Although the ambient temperatures during the two shifts were similar at 27 ^{o}C, during the afternoon shift no wind was observed, which can affect the sampling operation, leading forward the gasoline vapors to the passive samplers. This is the reason that the air sample from the pump inlet recorded 26 and 17 times higher concentrations of BTEX than pumps air sample and personal air, respectively. In this occasion, all vapors from the pump's inlet evacuation were leaded directly to passive sampler located a few centimeters above the inlet.

Discussion

Worker's exposure to BTEX compounds

In the gasoline service stations, exposure to benzene and toluene is 5 times higher than in enclosed parking garages although they are located in open air. The gasoline vapors emitted during the refueling operation seems to be more significant and acute exposure source than car exhausts driving in and out of car parking stations.

The BTEX concentration in both selected occupational groups were higher than ones recorded for traffic police officers, roadside and underground storekeepers, obtained by Jo et al [6]. In addition, occupational exposure to BTEX compounds, at enclosed parking garages and gasoline service stations, was significantly higher than exposure subjects in their homes as Fisher et al. and Skov et al. have determined [17,18].

The workplace exposure would be influenced by several parameters. The most likely parameters include the number of cars visiting a parking garage and the indoor ventilation for the parking

Comparison between the occupational levels of BTEX and the established TWA-TLV

Comparison of the mean concentrations of benzene and BTEX in selected workplaces, with the limits of exposure set or recommended by ACGIH, NIOSH and ECA was carried out. For benzene, a drastic reduction of TLV-TWA from 32 mg m^{-3} (10 ppm) to 0.32 mg m^{-3} (0,1 ppm) was proposed

Table 3. Mean concentrations (μg m^{-3}) and standard deviation of BTEX in personal air of workers, air samples of pumps at height 1 m above them, and air sample of pump inlet, obtained from gasoline service stations G1 and G2 on June 2001.

VOC μg m^{-3}	Gasoline service stations										
	G1				G2			G1+G2			
	(08:30- 15:30)		(18:15 – 01:15)		(09:30 – 16:30)						
	Workers *(n=2)*	Pumps *(n=3)*	Workers *(n=3)*	Pumps *(n=2)*	Workers *(n=2)*	Pumps *(n=2)*	Pump inlet *(n=1)*	Workers (n=7)		[1]Pumps (n=7)	
								Mean ± S	***Range***	Mean ± S	Range
Benzene	888 ± 296	214 ± 91	3258 ± 2109	1071 ± 337	244 ± 17	135 ± 73	3541	1731 ± 1918	232 - 5680	437 ± 460	84 - 1310
Toluene	1102 ± 809	307 ± 9	3526 ± 1937	1019 ± 82	593 ± 176	361 ± 9	7854	**1995 ± 1860**	**468 - 5756**	**526 ± 339**	**297 - 1077**
Ethylbenzene	152 ± 39	65 ± 8	458 ± 122	180 ± 2	111 ± 66	82 ± 14	2211	**272 ± 192**	**64 - 592**	**103 ± 54**	**58 - 181**
m+p -Xylenes	546 ± 110	219 ± 8	1645 ± 388	564 ± 3	463 ± 283	278 ± 13	9159	994 ± 662	263 - 2031	334 ± 159	210 - 566
o- Xylenes	208 ± 6	91 ± 18	606 ± 117	247 ± 28	144 ± 101	130 ± 32	3353	360 ± 244	73 - 702	147 ± 74	79 - 267
Σ $[BTEX]_1$[6]	2896 ± 1259	896 ± 78	9520 ± 4543	3081 ± 386	1555 ± 644	986 ± 22	26118	5352 ± 4766	1100 - 14760	1546 ± 1062	838 - 3354

[1] These samples, doesn't include the unique air sample taken from the pump inlet.

as intended change for the ACGIH in 1993-1994. However this proposed value was modified to 0.96 mg m^{-3} (0,3 ppm) before being accepted. In the last edition of TLVs for 1995-96, this value even appears as was proposed.

If we compare the results of this study from the parking garages, with the proposed limit (upper line in Figure 1) none of the air samples exceeded this value. Controversy, 64 % of air samples collected from both parking garages, exceeded the intended change for ACGIH and the established limit for NIOSH of 320 µg m^{-3} (lower line in Figure 1) with concentration range 325-574 µg m^{-3}.

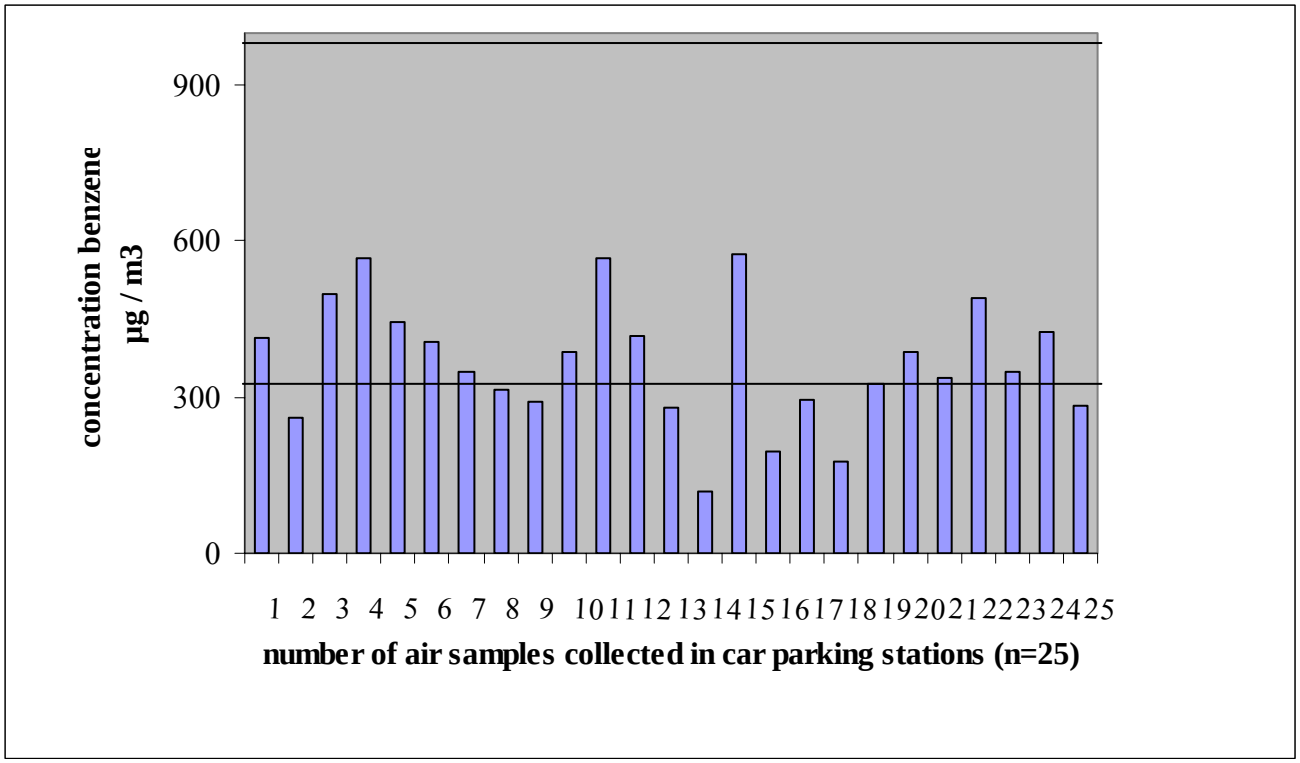

Figure 1. Benzene concentration levels in the parking garages. The upper solid line indicates the proposed limit of 960 µg m^{-3} and the lower solid line indicates the limit of 320 µg m^{-3} for benzene established by NIOSH.

In the gasoline service stations, benzene levels recorded were significantly higher than the proposed limits (Figure 2). For example, the mean concentration of benzene in personal air samples not only exceeded the limit of 320 µg m^{-3}, but it was recorded two times higher than the proposed limit of 960

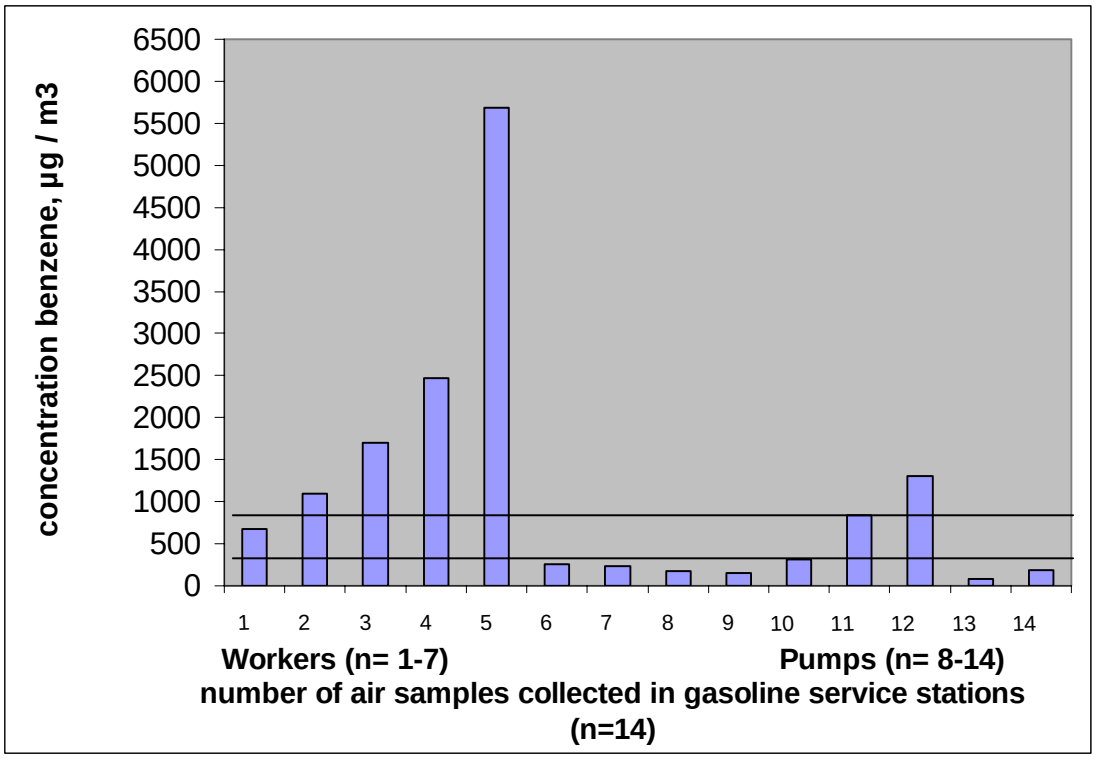

Figure 2. Benzene concentration levels in the gasoline service stations. The lower solid line indicates the limit value of 320 µg m^{-3} for benzene established by NIOSH and the upper one the proposed limit value of 960 µg m^{-3}.

µg m^{-3}. The 56 % of the personal air samples were higher than 960 µg m^{-3} with concentrations range 1097 – 5680 µg m^{-3}. In addition, the background benzene level from the air samples collected above the pumps, was higher than 320 µg m^{-3}, with a mean value of 437 µg m^{-3}.

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