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Binary Logistic Model for Exposure Assessment to Petroleum Hydrocarbons in Occupational Settings

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Abstract

Exposure to petroleum hydrocarbons in occupational environment is unprecedented especially when health safety protocols are not strictly followed. In this study two occupational setting i.e. auto-mechanic workshops and petrol-filling stations were used as target sites for monitoring exposure to polycyclic hydrocarbons (PAHs) among human workers. Subjects included in the study comprised of 60 auto-mechanics, 53 petro-filling workers and a group of unexposed general population (n=47). We analyzed work conditions, job duration through questionnaire followed by urinary and serum PAH-based biomonitoring to establish effect of exposure on PAH body burden. Results show auto-mechanics highly exposed based on serum (blood) PAH estimates and urinary 1-hydroxyprene concentrations. Significant differences ($p<0.01$) for these estimates were observed for this occupational group with petrol-pump workers and general urban population. Outcome of binary logistic model (regression based) revealed skin dryness & redness most prevalent among petrol-filling workers who had exposure 6 h day^{-1} or more (OR=4.57, 95% CI=1.42-14.71) on the other hand, allergic dermatitis shown due to chronic exposure among auto-mechanics when their job duration exceed from 10 years (OR=3.97, 95% CI=1.20-13.14). Emerging correlation between serum phenanthrene levels with smoking habit ($r=0.54$; $p<0.01$) further indicates a compounding effect of cigarette smoking in the presence of PAH in occupational settings. We conclude that serum PAH levels are useful proxy measures used as outcome variables in binary logistic model which appears to be a robust approach to predict petroleum hydrocarbon exposure.

Keywords: Polycyclic aromatic hydrocarbons; Exposure assessment; Urine; Serum; Biomarker

Introduction

Human exposure to various types of chemicals in urban environment is unprecedented. In Pakistan, although there is general awareness about harmful effects of such kind of exposure but in depth quantitative research to analyze exposure relation with associated risks is lacking. The environmental degradation in different cities of Pakistan has threatened the urban ecosystem to a great extent because of rising urban population and rural-urban flux of people. Consequently, huge numbers of vehicles are on road in major cities of Pakistan and traffic density is increasing day by day. A rough estimate has shown that on average 500 vehicles are registered daily in Islamabad while this number is around 300 for Rawalpindi city. This rising use of motors and vehicular function has demanded for more auto-mechanic workshops in the cities. The direct effect of this phenomenon was felt in the form of rapid growth in petroleum related occupations both in Rawalpindi and Islamabad areas. Consequently, people associated with such are occupations are believed to suffer more serious health issues compared to other general urban area population. However, the impact urban air pollution and rising human exposure to petroleum contaminants has been the focus of investigation in many developed countries but the same aspect has been neglected to a great extent in under developed countries [1]. The current investigation was planned with an aim to determine blood PAH concentrations in two petroleum related occupational groups to establish exposure effect relation with work conditions and to assess the suitability of selected PAHs as biomarkers. In addition, effort was also made to highlight exposure symptoms particularly physical one such as skin and other dermal problems that are commonly reported by workers during preliminary survey. We assume that the outcome of this research effort would substantially contribute in understanding the status of PAH body burden among occupational cohorts who are involved in petroleum related work and also to set safety guidelines for occupation exposure risks are unavoidable.

Materials and Methods

A detailed preliminary survey of Rawalpindi areas was conducted to select the locations of the petrol filling stations. Similarly, to know where auto-workshops are concentrated, several visits were performed and workers associated with auto-mechanical profession were briefed about the study. Both petrol pump workers and auto-mechanics were requested to involve in

the study and after their consent, they were recruited. From each worker, blood sample (3ml) was obtained and procedure for that was followed as described in our previous study [2]. From same worker, urine sample (mid day) was also was collected in 250ml sterilized plastic bottle. A short interview was also conducted to gather information about prevailing health status and any illness that was developed during occupation.

Serum PAH analysis was carried out for three polycyclic aromatic hydrocarbons which comprised of phenanthrene, pyrene and benzo[a]pyrene. For sample preparation and analysis, the method described in [2], was followed and HPLC (Shimadzu) was used for analytical work which ware provided with UV detection. For mobile phase, acetonitrile in varying concentrations along with double de-ionized water. The concentration of PAHs in the serum samples were identified by comparing the time of retention peaks of the standards with that of samples. One urinary metabolite, 1-hydroxyprene was also detected using HPLC. The sample preparation was sample as mentioned for serum estimation. Final calculation was performed by help of following formula [3].

$$\text{Concentration of unknown sample}(\text{ppm}) = \frac{\text{Con.of standard}(\text{ppm}) \times \text{Area}(\text{sample})}{\text{Area}(\text{standard})} \quad (1)$$

Statistical analyses were performed using SPSS version 16 for Windows®. Description statistics was carried out to reveal basic trends in the data. Mean, median and skewness values were used for this purpose. To predict the presence of exposure illness such as skin problems, binary logistic regression was performed using occupational parameters (job hours per day and job duration in years) as predictor variables. Calculation of regression coefficients was based on maximum likelihood principle through which odds ratio were found for each parameter. A probability level $p<0.05$ was considered statistically significant.

Result

The concentration of three PAHs detected in two occupational groups show wide ranges. However, the minimum values for control group was found relatively higher for serum phenanthrene estimation than both the occupational groups (Table 1). Among three PAHs detected in two exposure situation, pyrene was estimated in highest amount with 58.9µg L^{-1} and 55.69 g L^{-1} in petrol pump workers and auto-mechanics respectively. The mean and median values were close to each other for all the three PAHs (Table 1). Concentration of urinary metabolite i.e. 1-hydroxyprene was found in variable ranges for both the occupational groups as well as unexposed control population. Highest level was detected among auto-mechanics with 14.85µmol mol^{-1} creatinine followed by 2.59 and 2.93µmol mol^{-1} creatinine in control group and petrol pump workers respectively (Table 1). The skewness values indicated the normality feature of the data according to which the values obtained for serum phenanthrene, pyrene and benzo[a] pyrene for both the occupational groups had normal distribution whereas urinary metabolite concentration data was not normally distributed for all the cohorts investigated (Table 1).

Table 1: Summary of occupational and control population serum estimates for phenanthrene, pyrene and benzo[a]pyrene levels (µg L^{-1}) and urinary metabolite 1-hydroxyprene (µmol mol^{-1} creatinine).

PAH	Petrol Pump Workers (n=53) (Mg L^{-1})	Auto-Mechanics (n=60) (Mg L^{-1})	Control (n=47) (Mmol Mol^{-1} Creatinine)
Phenanthrene			
Minimum	0.15	0.7	0.89
Maximum	48.77	51.16	20.45
Mean	16.25	17.95	4.43
Standard Deviation	17.6	13.51	4.52
Skewness	0.95	0.87	2.17
Pyrene			
Minimum	0.45	0.86	0.56
Maximum	58.9	55.69	13.11
Mean	28.65	18.83	4.83
Standard Deviation	17.36	13.63	4.29
Skewness	0.87	0.89	0.76
Benzo[a]pyrene			
Minimum	0.46	0.24	0.05
Maximum	2.9	2.22	1.56
Mean	1.34	1.42	0.54
Standard Deviation	0.62	0.53	0.29
Skewness	0.55	– 0.09	1.52
1-Hydroxyprene			
Minimum	0.11	0.11	0.04

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Maximum	2.59	14.85	2.93
Mean	0.82	1.86	0.79
Standard Deviation	0.59	2.17	0.68
Skewness	1.7	5.5	1.5

Results of logistic regression are presented in Table 2 which accounts association between physical symptoms appeared on skin and job related factors such as years involved in particular job category and daily work hours. Although both the predictor variables had odds ratio greater than 1 however, only daily job hours was found significant (OR=3.4; 95%CI=1.07-10.77) (Table 3).

Table 2: Association between job related variables and skin symptoms among petrol pump workers analyzed by logistic regression.

Predictor Variables	Skin Dryness & Redness		N	OR	P-Value	95 % CI	
	No	Yes				Lower	Upper
Job Duration							
Less than 10 years*	11	17	28				
10 or more years	15	10	25	0.43	0.13	0.14	1.29
Job hours per day							
Less than 06 hours*	16	7	23	4.57	0.01	1.42	14.7
06 or more hours	10	20	30				
Total	26	27	53				

Table 3: Association between job related variables and skin symptoms among auto-mechanics analyzed by logistic regression.

Predictor Variables	Allergic Dermatitis		n	OR	P-value	95 % CI	
	No	Yes				Lower	Lower
Job Duration							
Less than 10 years*	22	6	28				
10 or more years	12	13	25	3.97		0.02	1.2
Job hours per day							
Less than 06 hours*	15	9	23	0.96	0.94	0.32	2.81
06 or more hours	19	11	30				
Total	34	19	53				

The relationship established between serum PAH levels with BMI and age has clearly indicated a trend of where age appeared to have more positive correlation especially with phenanthrene and benzo[a]pyrene concentrations (Figure 1). The reason age appeared to be good indicator of PAH body burden for petrol pump workers may probably be the nature of job as it demands constant gas filling activity and supervision right at the spot where exposure to volatile PAH compounds is maximum [4]. In addition, the dedication of workers to be associated with one type of job has exerted extra pressure on human body to be readily exposed for longer duration due to which higher PAHs estimates were with increase in age and manifested. Since this factor is more relevant to age rather than BMI therefore, higher regression coefficient values were observed for the former parameter.

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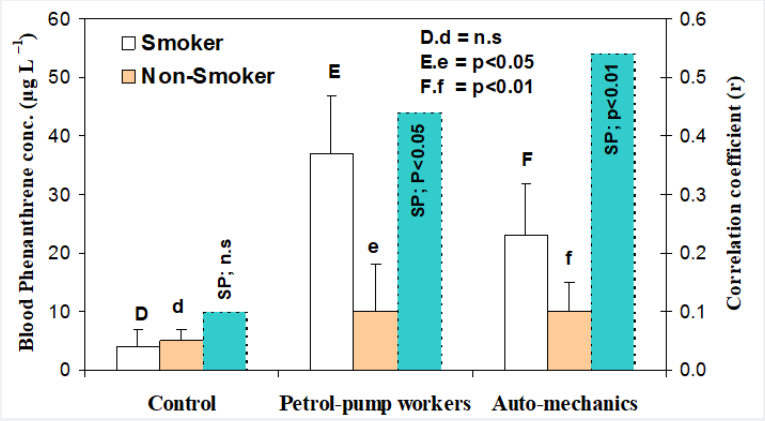

Figure 1: Comparison of serum phenanthrene among smoker and non-smoker categories for control and occupation groups. Bars with mean values showing standard errors and the light shaded bars represent correlation coefficients values between smoking and phenanthrene levels.

Discussion

We found a strong effect of occupational exposure to PAH with allergic dermatitis among auto-mechanics which seems an allergic response of occupational workers to PAHs that has been a neglected research aspect. In some studies only carcinogenicity has been observed with respect to PAH exposure [4-6]. Few studies reported lungs and respiratory diseases attributed to PAHs [7]. However, in few studies allergic response due to PAHs in occupational workers was also observed [1,8]. Therefore, it is assumed that findings of this investigation would further highlight the importance of allergic response as an important health factor to be included in exposure assessment studies.

The urinary metabolite concentration detected in our exposed group has two important implications. Firstly, there seems a definite relationship between nature of petroleum occupation and extent of exposure which was reflected by significantly higher mean values of 1-hydroxyprene in auto-mechanics than petrol pump workers. The other reason implies smoking status as crucial factors causing enhanced PAH exposure among occupational groups that has caused an additive effect on serum pyrene and benzo[a]pyrene levels which was reflected in urinary excretion of 1-hydroxyprene among occupational groups as compared to control population. Although various studies have emphasized on establishing relation between urinary excretion of PAH metabolite with exposure magnitude the findings of general population such as stated by [9] revealed 1-hydropyrene levels can be used as suitable biomarkers of PAHs in urine. Since the males verse females comparison was not valid in our study however, 1-hydroxyprene concentrations in different studies were reported higher in males as compared to general female population. One possible reason for that higher account was due to smoking habit and rate of smoking which is obviously reported higher among male [9,10]. Age factor seems another important aspect in this context which is to be accounted while interpreting urinary biomarker. Since children and young one perform frequent hand-to-mouth activities in daily routine, hence exposure and rate of inhalation from soil and other surfaces contaminated with PAHs may vary with the increase in age and resulting human exposure. Probably this is reason increase in age has reported to have decreasing effect of 1-hydroxyprene concentration [11,12]. Here the distance from emission source has also influenced the PAH body burden with respect to age. Urinary concentrations of 1-hydroxypyrene among children close to emission source had significantly higher body burden than those living farther from the emission source probably which was a coal-fired power plant [11].

In the present investigation, the selection of occupational groups was based on the assumption that petroleum related activities has differential effect on human exposure. For instance, workers at petrol filling stations, mechanics working at automobile workshops, traffic police wardens and professional drivers of buses, trucks, taxis and rickshaws are routinely exposed to PAHs but their exposure varies depending on how they protect themselves. Even highway toll bar attended mainly spend four to eight hours per day on roads with dense traffic. All these occupations, more or less have noticeable exposure which is reflected by variation in PAH serum concentration [13]. From results of serum concentration of three PAHs, it seems that auto-mechanics have highest exposure compared to petrol pump workers. Smoking has significant association with serum phenanthrene levels in both the petrol pump workers and auto-mechanics (Figure 2). The fact that smokers had high significant mean values for serum phenanthrene appeared to be a consequent effect of dual exposure i.e. one from smoking and the other resulting from occupational environment. These observations are further supported by the fact that smoking alone can be a considered an important exposure parameter for PAHs body burden [10]. Similar to our study where petrol pumps workers were involved as occupationally exposure work group, bus drivers was investigated assuming that their daily working hours put them under direct exposure to petroleum hydrocarbon [14]. Smoking and bus driving collectively has been found to

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cause significant rise in 1-hydroxyprene levels in urine samples when these were compared to control groups [13]. Probably this relation may have played an important role in establishing significant correlation with smoking PAH body burden in both the occupational groups which we have investigated. Although no female population was recruited in this study but reports have clearly indicated the exposure of PAH can have direct effect on urinary metabolite as cooking effect was observed to cause significant rise in urine concentration of 1-hydroxyprene among females [15].

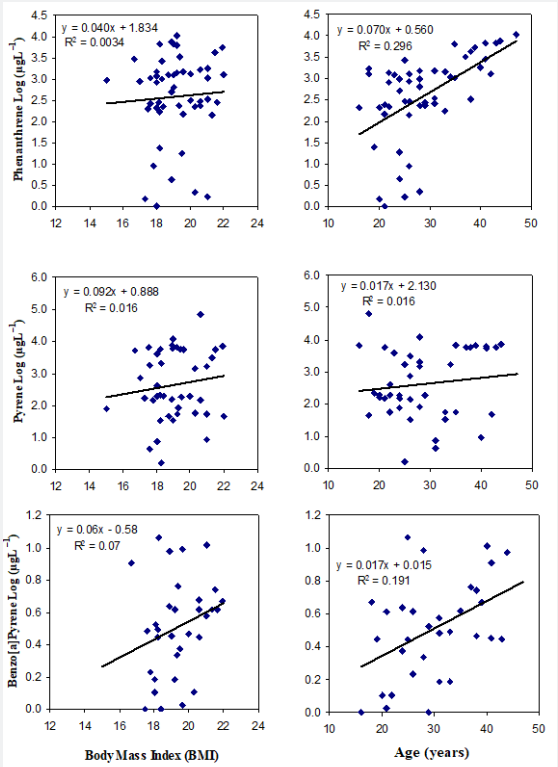

Figure 2: Relation between log transformed values for serum PAH levels and body mass index and age among petrol pump workers.

In urban environment, concentration of auto-mechanic workshops and petrol filling stations are potential sources of PAHs emission which can cause contamination of soil [12], ambient air used for breathing of directly exposed population [2]. Location of PAH emission source is crucial and reports have pointed out this aspect as distance effect on overall PAH body burden. For instance, compared to rural area children where traffic density is less, accumulation of PAH among children exposed to more densely populated areas was higher [16]. The present study indicates also accounts this aspect as number vehicles stop and pass at petrol filling stations as well as auto-mechanic workshops and hence the urinary 1-hydroxyprene concentrations along with corresponding benzo[a]pyrene and pyrene values reflect the exposure to emissions relation.

Conclusion

Serum PAH estimates are good proxy measures of petroleum exposure at filling stations and auto workshops. Inhalation and dermal contact are key sources of exposure to PAH in petroleum occupations and can cause severe health risk in long job hour conditions. Yearly health monitoring is imperative to minimize health risks associated with PAH exposure in Pakistan.

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Author Contribution

The study idea was conceived and planned by AR. Field sampling was conducted by IU and FN. Analytical work was performed simultaneously by AR and IU. Statistical analysis was carried out by AR and FN whereas writing of manuscript and editing was equally performed by all authors.

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