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ASSESSMENT OF OCCUPATIONAL EXPOSURE TOVOLATILE ORGANIC COMPOUNDS IN POULTRY WORKERS

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ARSTRACT

This study evaluated occupational exposures among poultry workers to five volatile organic compounds released from the extensive use of solvents and proteinaceous waste decomposition in the poultry farms. Concentrations of five volatile organic compounds VOCs (acetone, benzene, naphthalene, phenanthrene and pyrene) were measured in blood samples of 49 poultry workers from Pakistan to assess the occupational exposure. All of the concerned VOCs could be detected in more than 95% of blood samples. Levels of VOCs were higher in smokers compared to non-smoking workers i.e., acetone ($p=0.015$), benzene ($p=0.017$), naphthalene ($p=0.000$) and phenanthrene ($p=0.005$) except pyrene ($p=0.631$). Levels of VOCs also seemed to increase with the job duration of the workers ($p=0.001$). The prevailing hygiene conditions of farms surveyed seemed directly related with the frequency of safety equipment use during work. It is concluded that poultry workers are at a risk of occupational exposure to VOCs due to their work environment. It is highlighted from the findings that there is need for more complete studies to evaluate the exposures related to poultry industry in Pakistan and setting environment standards for these and other VOCs.

KEYWORDS: VOCs, Poultry Workers, Occupational Exposure, Smoking, Indoor Air

INTRODUCTION

Lately, assessment of exposure to hazardous chemicals has become thriving for an increasing number of chemical substances all around the globe. Volatile organic compounds (VOCs) are ubiquitous in the environment, frequently detected at workplaces (Heinrich-Ramm*et al.*, 2000). This is crucial as majority of people spend approximately 80% of their time in the indoor environments such as residences, public buildings and offices (USEPA, 1995). They are used in a broad scope in numerous industrial applications and people at work-places could experience a substantial absorption of VOCs owing to their lipophilic nature and high volatility (Garzaa*et al.*, 2012).

Regardless of the source, VOCs are simply absorbed through the skin and the respiratory tract. Once they enter into blood-stream, VOCs will possibly get to different target tissues, depending on the properties of the compound and the level of exposure, resulting in a number of damaging health effects, from acute to chronic toxicity, VOCs might also have carcinogenic effects (Das *et al.*, 2004; Garzaa*et al.*, 2012). Throat and eye infections, damage to liver and central nervous system may occur due to extended VOCs exposure (Das *et al.*, 2004).

World over poultry is one of the most vital source of protein for humans. On the other hand, severe environmental harms connected with the poultry industry have occurred along the management systems employed in the poultry industry. Widespread causes of pollution ensuing from poultry production are dust, odor and ammonia emissions. These diverse air pollutants are linked with health risks for both poultry workers and animals (Kocaman*et al.,* 2006). Odor problem is the foremost air quality issue associated to poultry farming (Moore *et al.,* 1995). At various stages of protein based waste decomposition for example feed debris, urine, feces, hair, skin, and bedding materials resulted odors in livestock houses (O'Neill and Phillips, 1991).

Farmer's exposure to a composite mixture of airborne substances poses risk to their respiratory system. Hypersensitivity andpneumonitis(lung disease), chronic bronchitis, bronchial responsiveness, organic dust toxic syndrome, asthma, and asthma-like syndrome are most common respiratory diseases experienced by farmers (Omland, 2002). In Pakistan, there is a lack of data on occupational exposure to health risks in poultry farm workers. All the workers are at an eminent risk of exposure to VOCs hazard. Poultry workers are exposed to these risks in our country attributed to their poor socioeconomic condition, low education levels and lack of knowledge and lack of waste handling training and hygiene.

Realizing a serious dearth of information about the VOCs patterns, quality and quantity, the present study is planned with the establishment and comparison of the exposure to VOCs at the selected farms, measurement of VOCs in the blood of poultry farms workers, the potential role of demographic variables in increasing VOCs exposure among poultry workers and comparison of VOCs levels in smoker and nonsmoker subjects.

MATERIALS AND METHODS

Study Subjects and Sampling

Two groups of poultry workers from Pakistan took part in the study: hatchery workers as the first group and poultry farm workers as the second. The workers (n=49) were found out to be 18-53 years old (median: 26.0 years), all males, living in an urban area of Pakistan (sampling period November 2012). Neither of the subjects have had any history of occupational exposure to VOCs. Among them were 28 non-smokers and 21 smokers. Prior to blood sampling a questionnaire was completed to elicit age, gender, education, smoking habit, job duration, work hours, safety equipment use, hygiene training, job satisfaction, work shifts, hygiene level of the work unit and medical history. Blood samples were collected in vacutainer tubes and kept at freezing temperature until analysis.

Analysis of Blood VOCs

Five major VOCs (acetone, benzene, naphthalene, phenenthrene and pyrene) were determined simultaneously using HPLC method according to Al-Daghri (2008). Briefly, half ml of serum (separated by centrifugation of blood samples) was diluted with half ml of methanol and vortexed (10-20 seconds). The solution was then added with a 5ml of a 1:1 hexane:diethyl ether mixture (vortexed again for a minute). Each sample was centrifuged for 5 minutes at 3000 rpm. Supernatant was removed and transferred to a new tube. This procedure was repeated for the same sample again and supernatant was extracted. It was the added with a little amount of sodium sulphate anhydrous, filtered and left to evaporate until dried completely. Dried tubes were added with acetonitrile solution (1ml) as a final step to complete sample preparation.

For quantitative analysis a little amount of the sample was injected into the HPLC systemSPD-10A VP-Shimadzu with UV detection (254 nm). Acetonitrile and deionized water were used as a mobile phase in 6:4 ratios at a flow rate of 1.25 mL min^{-1} and oven temperature of 40 ºC. Eluting analytes were quantified by ultraviolet detection (254 nm). Within a total run time of 25 minutes, all the five VOCs could be selectively quantified. Concentration of VOCs in the blood samples was calculated by calibration curve method which was developed by running the reference standards and the recovery rates obtained during validation were in range from 90 % to 97%.

Statistical Analysis

Main statistical parameters were generated with SPSS 16.0 for windows. Criterion for statistical significance was $p < 0.05$. The frequencies of all the demographic variables were calculated. Characteristics of surveyed population in response to the categories of the workers and association of different hygiene related parameters with the type of farm surveyed were calculated by chi-square. Linear regression was used to predict the hygiene level in the farms surveyed and the concentration of VOCs (acetone, benzene, naphthalene, phenanthrene and pyrene) in the blood of poultry workers. Concentrations of selected VOCs in blood were correlated to demographic and hygiene related parameters. The mean concentrations of selected VOCs in the blood of smokers and nonsmokers were compared using t-test. The same test was used to compare the mean concentrations of selected VOCs in the hatchery and farm workers.

RESULTS AND DISCUSSIONS

The results on the VOCs levels in blood are summarized in Table 1. Concerning all the 24 hatchery workers, all of the five VOCs were found in the blood samples. With respect to the single VOCs we found their levels in the following descending order; benzene, naphthalene, acetone, phenanthrene and pyrene (median: 3.85 vs. 2.99 vs. 2.09 vs. 0.83 vs. 0.58 ppm). The results for poultry farm workers were found in the following descending order; benzene, naphthalene, acetone, pyrene and phenenthrene (median: 1.72 vs. 1.027 vs. 1.02 vs. 0.157 vs. 0.059 ppm). This data is in good accordance with the international literature in the studies by Preuss et al. (2004), Wang et al. (1994), Swaen et al. (2010), Al-Daghri (2008), Singh et al. (2008) and Zhu et al. (2011). A significant difference was found between hatchery and farm workers for each of the VOC studied i.e., for acetone p=0.002 (statistically significant), for benzene p=0.003 (statistically significant), for naphthalene p=0.002 (statistically significant), for phenenthrene p=0.014 (statistically significant) and for pyrene p=0.05 (statistically significant). The mean values for the all the selected VOCs in blood were higher in hatchery workers than in the farm ones as is clear from the very significant P-Values demonstrated in the table. One of the main reasons for this might be that the hatchery unit was more vast and mechanized than either of these farms and that the workers were more exposed and thus contained higher levels of the contamination (Buckley *et al.*, 2005).

In our study (Table 1), there was a very significant difference between individual VOCs concentrations in smokers and non-smokers for most of the VOCs. Overall median concentrations for smokers and non-smokers for the single VOCs were found out to be acetone (median: 1.32 vs. 1.15 ppm, statistically significant p=0.015), benzene (median: 2.34 vs. 1.815 ppm, statistically significant p=0.017), naphthalene (median: 3.03 vs. 1.029 ppm, statistically significant p=0.000), phenanthrene (median: 0.902 vs. 0.0925 ppm, statistically significant p=0.005) and pyrene (median: 0.28 vs. 0.171 ppm, statistically insignificant p=0.631). Our study indicated that smoking might affect and exalt the level of blood VOCs. This lies in accordance with the past studies by Brugnone et al. (1989) and Angerer et al. (1991) as a number of studies on smokers have demonstrated the elevation of internal doses of some VOCs (Churchill et al., 2001; Guo et al., 2004).

Regression Analysis

The results on the regression analysis of the VOCs in blood are reported in Table 2. Five explanatory variables were regressed on each of the blood VOCs concerned. These variables are profession of the workers, job duration, work hours, safety equipment use and cleaning interval in the working unit. Our regression model is as follows:

$$Y_{(VOC)} = \beta_0 + \beta_{1\,(Profession)} + \beta_{2\,(Job\ Duration)} + \beta_{3(Work\ Hours)} + \beta_{4(Safety\ Equipment\ Use)} + \beta_{5(Cleaning\ Interval)}$$

As shown in Table 2, profession of the workers, working hours and safety equipment use did not seem to be much effective predictors in the regression model. Neither of the VOCs had any statistically significant ($p<0.05$) relationship with profession, work hours and safety equipment used by the subjects. However, safety equipment use came out as a very strong predictor in predicting hygiene level of the poultry units by having a strongly significant ($p=0.000$) relationship with the hygiene level and accounting for 73% change in hygiene.

Job duration has a positive and statistically significant ($p=0.001$) relationship with the concentration of acetone and benzene in blood samples. As the regression model for acetone and benzene was estimated, it was seen that increase of job duration by one year will increase the concentration of acetone and benzene by 50 % and 49 % respectively in the blood. Cleaning interval seemed to be an effective predictor for acetone and naphthalene levels prediction as seen in table. Both acetone and naphthalene had statistically significant relationship ($p= 0.013$ and 0.05) towards cleaning interval. As for the regression model, a negative relationship existed between cleaning interval and VOCs concentration. It was seen that one percent decrease in cleaning level would increase the blood concentrations of VOCs by 43% and 38% respectively.

Bratveit*et al.* (2007) pointed out that the concentration of benzene in the blood of full shift workers of crude oil process was significantly high as compared to flotation workers because they were associated with short time. Job duration, work hours and profession are reported to have effect on exposure level to VOCs in the indoor environment (Lerner *et al.*, 2012). The use of safety equipment (Rogers and Goodno, 2000) and efficient cleanliness and hygiene level (Dettenkofer*et al.*, 2004) reduce the risk of exposure in occupational environments.

The association between profession of the subjects and different socio-demographic variables gathered by questionnaire are presented in Table 3. Almost all of the variables (job duration, work hours, work shifts, hygiene training, cleanliness level and safety equipment use) were found out to be strongly associated with the profession of the workers as made clear by statistical significance ($p < 0.05$). To be considered, education level of the workers did not seem to vary significantly as both the groups were lowly educated and poor people of same status. This kind of differences may have an effect on the blood level of VOC contamination as described in the previous literature (Lerner *et al.*, 2012). Nature of the farms surveyed and some of the variables related to profession and health of workers were associated with each other (Table 4). Out of the five variables, four were found to be associated with the type of the farm very significantly as seen in table ($p < 0.05$) except stay time of the workers at the farm.

A farm can be viewed as a discrete work environment and this work environment has the ability to either satisfy or dissatisfy the employee working in it. Physical agents involved in the work environment can cause health hazards, producing tissue trauma (Rogers, 1997). Psychosocial factors in the working environment are important to consider and may lead to a variety of work related problems for instance staff dispute, absenteeism, staff turnover, low morale and decreased effectiveness of work (Fielding and Weaver, 1994). According to Malik *et al.* (2003) the visual assessment of hygiene level has been a poor indicator of cleaning efficacy. In the present study a significant relationship between the prevailing hygiene conditions of the farms and use of safety equipment was observed (Table 4). It appears that the frequency of safety equipment use increases the hygiene level of the farm. Safety equipment for example glove usage has produced significant reductions in physical injuries measured by glove perforations (Rogers and Goodno, 2000). Curtis (2008) pointed out that appropriate cleaning methods and proper cleaning chemicals can extensively minimize pathogen and infection levels.

VOCs concentrations were correlated to some demographic and hygiene related parameters (Table 5). The outcome suggested a strong correlation of VOCs concentration to some. Job duration appeared to be a very significant variable affecting the concentration of VOCs as clear from the coefficient values. It implies that increase in the job duration of subjects makes them more exposed to VOCs. Also we found a strong negative correlation between safety equipment use and VOCs concentration implying that the use of safety equipment in an occupation minimizes exposure to VOCs. The most significant results were found in the correlation of safety equipment use to the level of VOCs in the blood. These results are also supported by previous literature as described by Roger and Goodno (2000) that more the use of safety equipment, less will be the chances of exposure to harmful VOCs. Also socio-demographic factors play a role in the exposure level (Lerner *et al.,* 2012).

CONCLUSIONS

In conclusion, the presence of VOCs in occupational settings leads to a background burden of the workers there. VOCs were found in more than 95 % of the blood samples. Determination of blood VOCs seems to be a suitable measure in any environmental investigation representing internal exposure. Also, smokers showed VOCs concentrations increased than those of non-smokers. So it is concluded that tobacco smoke is a non-occupational source of VOCs and a major confounder in anticipating the impact of other environmental exposures (Wallace, 1989; Churchill et al., 2001).

It is positive that the occupational workers in poultry and hatchery units in Pakistan are at a risk of VOCs exposure and disease prevalence as a consequence of their low education, poor socio-economic status, lack of hygiene training and awareness. Poultry industry is a major producer of food in Pakistanbut also a major producer of potentially harmful wastes and emissions. It is crucial to compare the outcomes of this study with the worker protection legislation i.e. permissible exposure limits (PEL) and threshold limit value (TLV).

Table 1: Results of VOCs Analysis

Subjects	n		Acetone (ppm)	Benzene (ppm)	Naphthalene (ppm)	Phenanthrene (ppm)	Pyrene (ppm)
Hatchery Workers	24	Median	2.095	3.853	2.9915	0.831	0.589
		Mean	2.198	3.399	2.878	0.659	0.575
		Range	0.02-4.72	0.51-6.52	0-6.25	0.002-1.9	0.003-2.05
Poultry Farm Workers	25	Median	1.02	1.725	1.027	0.059	0.157
		Mean	1.0654	1.835	1.555	0.314	0.290
		Range	0.002-4.62	0.03-5.96	0-4.32	0-1.09	0-1.309
Smokers	21	Median	1.32	2.34	3.03	0.902	0.28
		Mean	1.878	3.019	2.816	0.600	0.473
		Range	0.03-4.72	0.51-6.52	0.76-5.02	0.002-1.24	0-1.34
Non-Smokers	28	Median	1.15	1.815	1.029	0.0925	0.171
		Mean	1.426	2.288	1.744	0.395	0.3978
		Range	0.002-4.69	0.03-5.98	0-6.25	0-1.9	0-2.05

Table 2: Regression Analysis for prediction of Blood VOCs

Constant	Acetone		Benzene		Naphthalene		Phenanthrene		Pyrene	
	1.332		2.265		2.848		0.624		0.393	
	$\beta_{Standarized}$	P-Value	$\beta_{Standarized}$	P-Value	$\beta_{Standarized}$	P-Value	$\beta_{Standarized}$	P-Value	$\beta_{Standarized}$	P-Value
Profession	-0.154	0.458	-0.166	0.448	-0.259	0.283	-0.042	-0.866	-0.261	0.311
Job Duration	0.509	0.001	0.498	0.001	0.018	0.909	0.069	0.681	0.260	0.137
Work Hours	0.308	0.060	0.136	0.424	0.111	0.550	0.075	0.697	0.192	0.337
Safety Equipment use	0.097	0.621	0.087	0.674	-0.021	0.927	-0.110	0.641	0.236	0.330
Cleaning Interval	0.013	0.013	-0.166	0.448	-0.387	0.05	-0.385	0.062	-0.315	0.133

Table 3: Characteristics of Surveyed Population in Relation to "Profession"

Variables	Categories	χ^2	P-Value
Job Duration	2-5 yrs	18.387	0.001
	5-10 yrs		
	10-15 yrs		
	15-20 yrs		
	20-25 yrs		
Work Hours	5-10 hrs	18.816	0.000
	10-15 hrs		
	15-20 hrs		
Education Level	Uneducated	5.115	0.164
	Middle		
	Matriculation		
	Intermediate and above		
Do you work in Shifts?	Yes	28.149	0.000
	No		
Hygiene Training	Yes	9.900	0.002
	No		
Cleanliness level	Poor	31.636	0.000
	Satisfactory		
	Good		
Safety Equipment Use	Yes	31.099	0.000
	No		

Table 4: Association of Different Hygiene Related Parameters with Type of Farms Surveyed

Variables	Category	χ^2	P-Value
Stay 24 Hours at the Farm?	Yes	0.260	0.419
	No		
Cleanliness level	Poor	31.636	0.000
	Satisfactory		
	Good		
Interval between Cleaning	1 Day	18.816	0.000
	2 Days		
	3 Days		
	More than 3 Days		
Hygiene Training	Yes	9.900	0.002
	No		
Safety Equipment Use	Yes	31.099	0.000
	No		

Table 5: Correlation of Blood VOCs Concentration to Demographic and Hygiene Related Parameters

	Parameters				
Parameters	**Acetone Concentration in Blood (ppm)**	**Benzene Concentration in Blood (ppm)**	**Naphthalene Concentration in Blood (ppm)**	**Phenanthrene Concentration in Blood (ppm)**	**Pyrene Concentration in Blood (ppm)**
Job Duration	0.602**	0.599**	0.284*	0.265	0.340*
Work Hours	-0.188	-0.253	-0.319*	-0.291*	-0.133
Stay 24 Hours At the Farm?	-0.238	-0.098	-0.344*	-0.095	-0.037
Safety Equipment Use	-0.391**	-0.391**	-0.415**	-0.375**	-0.198

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at tshe 0.05 level (2-tailed).

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