

Assessment of Occupational Exposure to Organic Solvents, Applied Safety Measures and Their Effect on Liver Function of Exposed Workers in Rubber Industry Tanta City – Gharbia Governorate

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Abstract

Background: In rubber manufacturing, health hazards from organic solvents are due to their metabolic conversion to more hazardous substances which may lead to liver injury.

Aim of the Work: To measure indoor environmental exposure to some organic solvents, to assess applied safety measures in the workplace and to investigate liver function of occupationally exposed workers.

Subjects and Methods: This study was a cross sectional study conducted on rubber factory production departments in the period from July 2017 up to October 2018. The study included 120 workers. Interview questionnaire with exposed workers and filling an audit workplace observational checklist by the researcher were used as tools of the study. Measuring environmental indoor exposure to some volatile organic compounds (benzene, toluene, ethylbenzene and xylene) was done by gas chromatography (GC). Liver function tests for exposed workers were measured.

Results: Environmental monitoring revealed higher levels of exposure to benzene, ethylbenzene and toluene (2.13, 560 and 380mg/m³ respectively), while level of xylene was within normal. The mean total score percent for checklist of applied safety measures was 17.94%+7.93%. The study indicated lack of training programs with no periodic medical examination was made for workers. The majority of workers had occupational exposures to chemicals, fumes and dust (70.8%, 73.3% & 60%) respectively. Liver function tests were found to be normal in the majority of workers (93%).

Conclusion and Recommendations: There were insufficient applied safety measures in the factory & increased levels of benzene, ethylbenzene and toluene more than the permissible exposure limits. So, regular environmental monitoring, applying the standard safety measures, and periodic medical examinations for workers are needed.

Key Words: *Organic solvents – Liver function – Rubber industry workers.*

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Introduction

RUBBER is derived from both natural and synthetic sources. Natural rubber comes from diagonal incision in the tree trunk named "Hevea brasiliensis" where latex is extracted from it and coagulated by adding acid. While synthetic rubber (70% of rubber) is obtained by mixing products of cracking process of crude oil with chemicals to make latex. International Agency for Research on Cancer (IARC) classified rubber industry as group 1 carcinogenic to humans since 1987. Rubber manufacturing faces various potential health hazards among exposed workers due to the harmful substances used in the chemical reactions in the process of manufacturing as well as hazards arising from rubber wastes and emissions [1].

In rubber manufacturing, there are multiple occupational exposures to dust and to a variety of volatile organic compounds "VOCs" as benzene, toluene and xylene [2,3]. Health hazards of these compounds are due to their metabolic conversion to more hazardous substances in liver which may cause organ injury including liver. Multiple factors may increase hepatotoxicity risk as long duration of exposure without use of personal protective equipment, obesity, drugs and genetic factors [3].

Clinical picture of occupational liver disease may be acute, subacute or chronic. Liver steatosis is a good clinical marker for solvent hepatotoxicity. The main pathological mechanisms responsible for solvent induced functional and organic damage are: cytochrome P450 dysfunction, mitochondrial dysfunction, inflammation and oxidative stress [2]. Three conditions must be present for diagnosis of occupational toxic hepatitis [4,5]: (1): Liver damage occur after occupational exposure to a hepatotoxic

substance, (2): Increased hepatic enzymes at least to double the upper limit of normal levels and (3): Exclusion of other causes of liver disease. Elevation of serum enzymes as alanine aminotransferase (ALT) and aspartate aminotransferase (AST) reflects hepatic parenchymal cells damage. Bilirubin, bile salts and proteins such as albumin and clotting factors are indicators of liver dysfunction [6].

The specific objectives of the present study were to measure environmental work place exposure to some organic solvents, to assess applied safety measures in the work place and to investigate liver function of workers occupationally exposed to organic solvents in rubber factory.

Subjects and Methods

A cross sectional study was carried out on all twelve production departments of the Tanta rubber factory. The factory production departments included (medium pressure hoses, profiles, radiator hoses, molded, battery cases, latex gloves, rubber lining, high pressure hoses, mixing, boilers, quality & maintenance). Data were collected from July 2017 to October 2018.

All workers in all production departments of rubber factory (120 workers), who were available during the period of the study and accepted to participate, were our study participants. Workers in administrative departments, workers with history of liver disease before engagement into this factory and those who spent less than 2 years at work were excluded from the study.

The study tools were a predesigned structured questionnaire sheet filled by researcher through direct personal interviews with workers including socio-demographic data, present occupational history, past occupational history and current medical condition (Tool I).

Measurements of liver enzymes level: Aspartate transaminase and Alanine transaminase (AST & ALT) were done for 114 workers who agreed to give blood samples. Two milliliters of blood were collected from each subject by venipuncture under aseptic condition and were left to clot. Blood samples were stored at $\pm 4^{\circ}\text{C}$ in ice box, then centrifuged for serum preparation. Measurement of other liver functions as blood albumin level, total blood bilirubin level & blood prothrombin time by the same procedure was done for workers with elevated liver enzymes (Tool II). A modified workplace observation checklist based on occupational safety and health administration (OSHA) standards and international labor office standards (ILO) was filled by the researcher to check applied safety

measures at work place (Tool III) [7, 8]. Environmental monitoring of workplace by measuring the level of some Volatile Organic Compounds "VOCs" in the most polluted rubber production department (mixing department) was carried out by the National Research Centre " in Giza, Egypt " according to the international requirements developed by NIOSH during whole shift working hours (8 hours). VOCs were collected using activated charcoal tubes (OR-BOTM-32 activated coconut charcoal 20/40) and air was drawn through the charcoal tubes, using vacuum pumps calibrated to draw 1L/min. After sampling time, the charcoal tubes were removed from the sampling train and two open sides were tightly closed using special caps to avoid any desorption then the samples were put into special plastic bags that were tightly closed and kept at -10°C in a freezer until processed. Sample analysis was done by Hewlett-Packard gas chromatography (GC) for solvents, fitted with a flame ionization detector (FID). Measured organic solvents were (benzene, toluene, ethylbenzene and xylene) (BTEX) (Tool IV) [9].

Ethical consideration: Approval from the ethical committee of Tanta Faculty of Medicine was obtained before starting the study. Subjects were informed about the purpose and procedures of the study. Oral consent and approval were obtained from each subject to participate in the study. Confidentiality and privacy were guaranteed during the whole period of the study.

Statistical analysis of data: Data was statistically analyzed by using SPSS-V21. Numerical data was presented as mean and standard deviation (SD) and categorical data was presented as number and percentage. Parametric tests were applied for normally distributed data such as ANOVA. For categorical variables, Chi-square test was used for analysis and when it was found inappropriate, it was replaced by Fisher's and Monte Carlo exact tests.

Results

The sample included 120 workers with a mean age of 38.62 ± 7.36 years. The majority of workers (94.2%) were married. Most workers (80.8%) were from rural areas. Regarding educational level, 83.4% of workers had secondary level of education and only 10% percent had university level (Table 1). Mean years of experience in current job was 11.83 ± 4.77 . Technicians represented the most of workers (79.1%). Regarding occupational exposures, most workers (83.3%) reported exposure to heat, 77.5% exposed to noise and 73.3% exposed

to fumes. While exposure to chemicals & dust were reported by 70.8%, 60%, respectively. Workers who had previous jobs before engagement to work in current job were 39.2% with 17% of them had similar previous chemical exposure (Table 2). Benzene, ethylbenzene, toluene and xylene were measured and revealed higher levels of 2.13, 560 and 380mg/m³, respectively. While level of xylene was within the accepted level (307mg/m³) (Table 3). Workers reported that pre-employment medical examination was done to 95.8% of them with no periodic medical examination. Workers who were trained on safe work practice and on dealing with fire accidents were only 10.8%. While, only 3.3% of workers reported training on dealing with emergency situations (Table 4). It was found that the mean total score percentage for all items of checklist of safety measures in all departments of the rubber factory was very low (17.49%±7.93%). The total mean score percentages for worksite in general and for fire protection were 42.59±19.44 and 40.91±17.12, respectively. Total percentage score for hazardous materials was 38.1±17.58. For other items, the total percentage scores were very low ranging from zero for personal protective equipment to 26.32±16.34 for machine guarding (Table 5). Six workers out of 120 workers refused to give blood samples. Liver enzymes were measured with eight workers (7%) had elevated ALT level and Two workers had elevated AST level. Only two workers had both enzymes elevated. Other liver function tests as total blood bilirubin, serum albumin and prothrombin time revealed normal values (Table 6).

Table (1): Socio-demographic characteristics of studied workers.

Socio-demographic characteristics	Number (n=120)	Percent %
<i>Age in years:</i>		
20-	12	10.0
30-	56	46.7
40-	40	33.3
50-60	12	10.0
Range	22-60	
Mean ± SD	38.62±7.36	
<i>Marital status:</i>		
Single	6	5.0
Married	113	94.2
Divorced	1	0.8
<i>Residence:</i>		
Rural	97	80.8
Urban	23	19.2
<i>Educational level:</i>		
Illiterate	3	2.5
Primary	5	4.1
Secondary	100	83.4
University	12	10.0

Table (2): Work related data of studied workers.

Variables	Number (n=120)	Percent %
<i>Years of experience in current job:</i>		
<5	6	5.0
5-	22	18.3
10-	78	65.0
15-	8	6.7
20+	6	5.0
Range	2-34	
Mean ± SD	11.83±4.77	
<i>Type of job:</i>		
Production worker	2	1.7
Guard worker	3	2.5
Fire fighter	1	0.8
Maintenance worker	2	1.7
Observer	4	3.3
Technician	95	79.1
Chemist	5	4.2
Department head	8	6.7
<i>Occupational exposures:</i>		
Chemicals	85	70.8
Dust	72	60.0
Fumes	88	73.3
Heat	100	83.3
Noise	93	77.5
Previous jobs with similar chemical exposures	8	17.0

Table (3): Concentration of some VOCs in the environment of the rubber factory.

VOCs	Concentration	Standard Limit (10)
Benzene (mg/m ³)	2.13	1.6
Ethylbenzene (mg/m ³)	560	434
Toulene (mg /m ³)	380	188
Xylene (mg /m ³)	307	434

Table (4): Available safety measures in the factory as reported by the studied workers.

Variables	Number (n=120)	Percent %
Pre-employment medical examination	115	95.8
Periodic medical examination	0	0.0
Use of protective equipment	2	1.7
Training on safe manipulations and safe work practice	13	10.8
Training on dealing with fire accidents	13	10.8
Training on dealing with emergencies	4	3.3

Table (5): The mean total score percentage for checklist items of safety measures.

Item	Range	Mean \pm SD
Workplace in general	66.67	42.59 \pm 19.44
Fire protection	63.64	40.91 \pm 17.12
Hazardous materials	57.14	38.10 \pm 17.58
Personal protective equipment, ventilation & records	.00	.00
Environmental conditions	33.33	17.59 \pm 10.00
Hazardous chemical exposure	22.73	13.26 \pm 6.84
First aid requirements	50.00	17.50 \pm 13.57
Emergency response	33.33	16.67 \pm 17.41
Electrical safety work practices	14.29	5.36 \pm 5.38
Machine guarding	52.63	26.32 \pm 16.34
Total score percent	26.85	17.94 \pm 7.93

Table (6): Liver enzymes & other liver function tests of studied workers.

Liver enzymes	AST (n=114)		ALT (n=14)	
	N	%	N	%
Normal	112	98.2	106	93
Elevated	2*	1.8	8	7
Other tests	Mean \pm SD		Normal range	
Total blood bilirubin in mg/dl	0.64 \pm 0.1		up to 1mg/dl	
Serum albumin level in mg/dl	4.1 \pm 0.57		3.5–5.5mg/dl	
Prothrombin time in sec	12.17 \pm 1.03		11–14sec	

Discussion

Many chemicals are used to create the necessary properties of the final rubber product. The most important chemicals are organic solvents [2,3]. Long term heavy solvent exposure is hazardous to the liver [11]. Regarding environmental workplace exposure to some organic solvents, the present study revealed higher levels of benzene, ethylbenzene and toluene, while level of xylene was within the acceptable level. A study made by Lee N et al., [12] on Korean tire manufacturing found that polycyclic aromatic hydrocarbons were within the standard limit.

The present study found that majority of workers were not trained on safe manipulations with the chemicals or on dealing with fire accidents which is consistent with the study done by El Hamid Hassan et al., [12] that was performed on 92 male workers exposed to organic solvents in paint factory in Zagazig, Egypt and revealed insuffi-

cient knowledge about the safe manipulations with commonly used solvents. Personal protective equipment "PPE" is one of the basic protective measures. The current study found that masks and gloves were used by only (1.7%) of workers. R.Vermeulen et al., [14] in Netherlands reported increased use of PPE especially gloves (45%) by exposed workers. This difference may be due to their high knowledge and positive attitude on importance of safe manipulations with chemicals.

The current study revealed that only 6.7% of workers had elevated ALT level and 1.7% of workers had elevated AST level. The effect of exposure to organic solvents on liver enzymes of the exposed workers is controversial. Some studies revealed a significant effect on liver function [15,16] while, other studies didn't [17,18]. The results of the current study are similar to a study done by El Mahdy & Radwan [19] on 68 workers occupationally exposed to mixture of organic solvents in painting industry in Cairo, Egypt and revealed that ALT and AST were within normal range with no statistically significant difference between the exposed and the control groups. This might be because the levels of organic solvents that were not so far from the standard permissible values. Our findings are also in line with Aminian et al., [20] in Iran who carried out a study to evaluate the hepatic damage due to exposure to organic solvents. The study reported there were no statistically significant difference between cases and controls.

In Iran 2015, a survey study on rubber industry workers exposed to a mixture of organic hydrocarbons including benzene, toluene and xylene reported that mean levels of ALT and AST in exposed workers were normal. Although, the exposure rate to each single chemical was within the permissible exposure limit, the mean of exposure to mixture of hydrocarbons was greater than the permissible exposure limit in some places [21]. Contrary to Hasani et al., [22] in Egypt that conducted a study on 63 workers in furniture manufacture occupationally exposed to mixture of solvents (mainly toluene, styrene and benzene) and 27 healthy controls. The study found that all parameters of liver function were high among exposed groups. Serum ALT was increased by increasing the duration of exposure "a sensitive biomarker for hepatic affection".

The rise of liver enzymes levels (AST, ALT) reflects damage of liver cells but, they are not sensitive enough for the diagnosis of early stages of occupational liver dysfunction. Therefore, some studies reported higher sensitivity of serum bile

acids for diagnosis of liver dysfunction [23]. The difference between various studies might be due to different sample size, type of solvents, duration of exposure and application of safety measures in work place including use of protective equipment [11,24]. Also, several predisposing factors should be taken into consideration while assessing hepatotoxicity due to solvent exposure such as alcohol use, hepatotoxic drugs, genetic factors and obesity [25]. In the present study, rotation of workers between different departments of the rubber factory, increased absenteeism from work and less sensitivity of liver tests were the most important limitations of the study.

Conclusions: Environmental monitoring revealed higher levels of benzene, toluene and ethylbenzene. Total mean score for all items of check list of safety measures in the rubber factory was insufficient. Workers didn't receive any training programs about safe work practice. Liver function tests had normal levels for the majority of exposed workers.

Recommendations: Dissemination of these results to the head of the rubber factory and to the responsible managers to apply the suitable engineering and environmental controls to occupational exposures to chemicals, heat, noise, fumes and dust. Health education of workers about the hazards in rubber manufacturing & training them on safety measures. Make sure that workers follow safe work practices. Regular environmental monitoring and regular periodic medical examinations should be done for exposed workers.

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تقييم التعرض المهني للمذيبات العضوية وإجراءات الوقاية ومدى تأثيرها على وظائف الكبد للعاملين المعرضين بصناعة الكاوتشوك بمدينة طنطا - محافظة الغربية

المقدمة: هناك استخدام واسع للمذيبات العضوية في العديد من الصناعات بما في ذلك صناعة المطاط التي قد تؤدي إلى مخاطر صحية مختلفة للعمال وقد تؤثر على البيئة المجاورة إذا لم يتم تطبيق تدابير السلامة بشكل صحيح.

الهدف من الدراسة:

- ١- تقييم تدابير السلامة التي يتم تطبيقها في مكان العمل.
- ٢ - قياس التعرض البيئي لبعض المذيبات العضوية في مكان العمل.
- ٣- قياس وظائف الكبد للعمال المعرضين مهنيًا للمذيبات العضوية في صناعة المطاط.

طريقة البحث: دراسة مقطعية عرضية أجريت على جميع العاملين في جميع أقسام مصنع المطاط بمدينة طنطا (١٢٠ عام) في الفترة من يوليو ٢٠١٧ إلى أكتوبر ٢٠١٨. وتم استخدام إستبيان مقابلة للعمال، وقائمة الملاحظة في مكان العمل. وتم أخذ عينات دم من العمال بالمصنع لقياس وظائف الكبد.

نتائج البحث: معظم العمال كانوا يتعرضون للحرارة والضوضاء والأبخرة. بينما من تعرضوا للمواد الكيميائية والغبار كانت نسبتهم (٧٠.٨٪)، ونسبة العمال الذي كان لديهم نفس العرض الكيميائي السابق للمذيبات العضوية ١٧٪. وقد تم الفحص الطبي للعمال قبل التوظيف ولكن لا يتم إجراء فحص طبي دوري من قبل المصنع. لم تكن معدات الوقاية الشخصية متاحة ولم يكن هناك دورات تدريبية كافية من قبل المصنع على التعامل الآمن مع الطوارئ. وبعد أن تم إجراء إختبارات وظائف الكبد للعمال أتضح أنها طبيعية في غالبية العمال. وقد تم قياس مستوى بعض المركبات العضوية المتطايرة في الغلاف الجوي لمصنع المطاط خلال ساعات العمل (٨ ساعات) وفقاً للمعايير الدولية وكشفت القياسات مستويات عالية من البنزين والإيثيل والتولوين (٢٠١٣، ٦٥٠ و ٣٨٠ ملغم/م^٣ على التوالي) بينما كان مستوى الزيلين في الحد المسموح به.

الخلاصة: أن التعرض للمذيبات العضوية في مصنع المطاط له تأثير ضعيف على وظائف الكبد للعاملين المعرضين على الرغم من مستويات عالية من بعض المذيبات العضوية وأن أغلب الأقسام بالمصنع لم تكن كافية فيما يتعلق بتدابير السلامة.

التوصيات:

- ١- ينبغي تطبيق تدابير السلامة مع استخدام ضوابط هندسية وبيئية مصممة تصميماً جيداً للتقليل إلى أدنى حد من التعرض للمواد الكيميائية ومستويات الضوضاء الزائدة وتوفير التهوية الكافية.
- ٢- أن يتلقى جميع العمال المعرضين ببرامج التدريب المناسبة وعمل تدريب باستمرار على ممارسات العمل الآمنة مع الأخطار في المصنع وكيفية التعامل مع الحرائق وحالات الطوارئ والإستخدام السليم لمعدات الحماية الشخصية المطلوبة.
- ٣- أن تتم القياسات البيئية للمواد الكيميائية والمذيبات العضوية بانتظام مع قياسات مستويات الضوضاء والغبار والحرارة في مكان العمل من خلال الطرق المناسبة.
- ٤- إجراء الفحص الطبي الدوري بانتظام كل ٦ أشهر للكشف المبكر عن أي مشاكل صحية.