

Liver Enzyme Status of Rubber Industry Workers from West Bengal, India

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Abstract

Original Research Article

The rubber industry workers are frequently exposed to different organic solvents, dust, fumes which can cause health hazards including liver injury. The purpose of the present study is to investigate the occupational exposure to rubber industry effluents on liver and kidney function of workers of West Bengal, India. This study was carried out in 170 male rubber industry workers and 50 control group workers of Hooghly district of West Bengal. The study parameters consist of liver enzymes and some biochemical parameters. Besides, environmental parameters were taken from recent factory records of environmental analysis. A modified questionnaire has been used to study the socio-demographic pattern of workers and control group. The result of this study revealed that physical parameters, liver enzymes, and bilirubin (direct and indirect) levels were significantly higher in rubber industry workers compared to control group. But other biochemical parameters- total protein and albumin level significantly decreased compared to control. But random blood sugar, creatinine and CRP values significantly higher in rubber workers compared to control, indicating stress on hepatic and renal function among workers of rubber industry. The results of our study also focuses that workers of different departments of rubber industry like mixing (most dusty), boiler and production units and office (less dusty) have significantly higher liver enzymes and CRP level indicating association of higher level of pollutants with liver function and inflammatory reaction. Crude OR values indicate BMI and shifting pattern of duty in rubber industry can alter the metabolic pattern and responsible for elevated liver enzymes. But multiple logistic regression equations indicate alcoholism and CRP level are the risk factors for elevated liver enzymes. The study concluded that exposure to rubber dust and mixture of hydrocarbons have extensive effects on liver function parameters, creatinine level and CRP. Therefore, evaluation of transaminase of rubber industry workers are beneficial for early detection of hepatocellular injuries. Thus, environmental monitoring, use of sufficient safety measures, incorporation of modern technologies and equipment will protect the health of liver and reduces mortality and morbidity of workers in these industries.

Keywords: Rubber industries, Organic solvents, liver enzymes, kidney function, CRP, biochemical parameters.**Copyright © 2026 The Author(s):** This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY-NC 4.0) which permits unrestricted use, distribution, and reproduction in any medium for non-commercial use provided the original author and source are credited.

INTRODUCTION

The workers of rubber manufacturing sectors are frequently exposed to various combinations of chemicals, such as rubber dust, fumes, and N-nitrosamines, which have been related to a number of health issues. Such exposures have been primarily affecting the digestive, cardiovascular, and respiratory systems (Hidajat *et al.*, 2019) and also associated with increased risks of neoplastic and non-neoplastic diseases. N-nitrosamines have a well-documented carcinogenic potential, but despite the liver being the primary organ involved in xenobiotic metabolism and detoxification, little is known about their hepatotoxic effects. Continuous exposures to industrial chemicals, even in low levels, can have a very deleterious effect on the liver

system. Chemicals used in the rubber industry, such as nitrosamines, benzene derivatives, and organic solvents (such as toluene and dimethyl formamide), can cause impairment of hepatic function, inhibit enzymatic activity, and induce oxidative stress. According to studies conducted in rubber plants in Iran and Egypt, workers who have been exposed to chemicals at work very often have significantly higher levels of alanine aminotransferase (ALT), a marker for hepatocellular damage, than controls who have not been exposed to such kinds of chemicals. This suggests that occupational chemical exposure causes subclinical hepatic impairment (Elghmry *et al.*, 2019; Rafeemanesh *et al.*, 2015). It has been seen that workers exposed to petrochemicals and solvents have elevated serum levels of gamma-glutamyl transferase (GGT), aspartate

aminotransferase (AST), and ALT, indicating hepatic damage even at low exposure levels. Additionally, occupational exposures to such chemicals, lifestyle and metabolic factors may have an impact on the hepatological profiles of rubber industry workers. A strong correlation has been found between modifiable risk factors like alcohol consumption, obesity, smoking, and physical inactivity and elevated levels of liver enzymes like ALT and GGT (Niemelä, 2016). The biomarkers (ALT and GGT) give an insight towards extrahepatic morbidities like diabetes, hypertension, and cardiovascular diseases in addition to hepatic stress (Niemelä, 2016). The risk of hepatic dysfunction of rubber industry workers may increase due to the synergistic effects of simultaneous exposure to metabolic stressors and environmental toxins. Furthermore, chronic exposure to hepatotoxic chemicals may affect the systemic conditions and cause hypertension, a leading cause of cardiovascular morbidity and mortality globally. The correlation between cardiovascular and liver stressors emphasises how the evaluation of liver function of rubber industry workers is important in occupational health surveillance programmes. In exposed groups, this kind of integrated approach may prevent the long-term effects and help in the early detection of hepatic dysfunction. In India, the occupational health of workers, particularly those in industries such as the rubber industry, may be deteriorating. So to fill the gap, we further study the health of such workers.

AIMS AND OBJECTIVE

The objective of the current study is to assess the occupational exposure to rubber industry effluents on liver and kidney function of workers of West Bengal.

METHODS

This cross-sectional study was carried out in the rubber industries of the Hooghly district, Dankuni area of West Bengal. The study group consisted of 170 male rubber industry workers and 50 control group workers of almost similar socio-economic backgrounds. The control group workers are mainly small businessmen, shopkeepers, and non-teaching employees of colleges. The study participants were selected through a simple random sampling method, ensuring a representative and unbiased sample. The representative sample size was calculated using PS power and sample size calculator software (version 3.1.6).

Ethical Considerations: The study has been approved by the Institutional Ethical Committee of Raja Peary Mohan College under the University of Calcutta [Ref No. 1/2022]. We obtained the permission of the authorities after describing the goal of the study to the participants and management of the rubber industries. Individual consent was taken before starting our work. The data were only used for research purposes and subject to the Helsinki Declaration. Individual workers

willing to participate in a health check-up were assured confidentiality and anonymity of the data.

Inclusion criteria

- Participants were required to be male.
- Age ranges from 20 to 60 years.
- Participants must not have any prior history of cardiorespiratory and metabolic disorders.
- Workers working more than one year in this industry with a minimum work duration of 8 hours per day.

Study of Physical Parameters

Physical characteristics like age, height, weight and body mass index were taken by standard protocol. An Aadhar card, anthropometric rod and weighing machine were used to note age, height and weight, respectively. BMI was calculated using the formula: body weight (in kg) divided by the square of body height (in meters)².

Socio-demographic Data

Socio-demographic-related data were collected using a pretested questionnaire by interview method comprising duration of service, smoking habit, education, monthly income, family members, no. of working days per week, use of protective equipment, shifting pattern of duty, alcohol intake, and digestive problems.

Laboratory Diagnostics

Collection of Blood Samples: A volume of 5 ml of venous blood was collected from the median or antecubital vein, of which 3.5 ml and 1.5 ml were immediately transferred to EDTA vials, respectively, and the following biochemical parameters were studied.

The parameters are –

- Blood sugar – By GOD/POD method (Tietz, 1982)
- ALT or SGPT and AST or SGOT – By IFCC (International Federation of Clinical Chemistry) method without pyridoxal phosphate (Lawrence A. Kaplan et al., 2003)
- ALP – By IFCC kinetic assay (Young, 1997)
- Total protein– By modified Biuret assay (Young, 1997) and total albumin by Bromocresol Green method (Young, 1997)
- Gamma glutamyl transferase – By carboxy substrate method (Young & Friedman, 2001)
- Bilirubin – By the Jendrassik-Grof method (Guder *et al.*, 2002)
- Creatinine – By the Jaffe's Kinetic method without deproteinisation (Helger *et al.*, 1974).

Study of Biochemical Parameters: Serums of the blood samples were used to measure random blood glucose, creatinine and C-reactive protein (CRP).

Random blood glucose was measured by the protocol of Tietz, (1982) while the Jaffe kinetic method without deproteinisation of Helger *et al.*, (1974) was followed to quantify creatinine. Measurement of CRP was done by following the protocol of Brindle *et al.*, (2010).

Calculation of R ratio: The ratio compares the elevation of two different liver enzymes, ALT (Alanine Aminotransferase) and ALP (Alkaline Phosphatase). Because different labs have different normal ranges, the formula uses the "Upper Limit of Normal" (ULN) as a baseline.

Formula R = (ALT value ÷ ALT ULN) ÷ (alkaline phosphatase value ÷ alkaline phosphatase

ULN). An R ratio of >5 indicate hepatocellular injury, R <2 indicate cholestatic injury (damage of bile duct), and R = 2–5 indicate mixed pattern guiding diagnosis for liver injury (Shaikh *et al.*, 2024).

Statistical analysis: The statistical software program SPSS (version 26) was used to analyse the data. The result obtained from the analysis was presented in tabular form. Descriptive statistics, correlation, ANOVA, binomial logistic regression and odds ratio were calculated.

RESULTS

Table 1: Environmental Analysis of Rubber Factory

Air composition	National standard	International standard	WHO Standard (AQG)	Present study at factory
Respirable particulate matter (µg/m ³)	50	16.66	15	251
Suspended particulate matter(µg/m ³)	167	260	5-15	534
SO ₂ (µg/m ³)	40	41.66	13.33	4.38
NO ₂ (µg/m ³)	40	40	8.33	21.85
CO (mg/ m ³)	2	10	1.33	1.22
Air temperature (°C)				
Plant area				36
Mixing area				34
Boiler department	18-23	-----	-----	40
Office area				26
Humidity (%)				
Plant area				81
Mixing area				89
Boiler department	25-55	-----	-----	86
Office area				58

Table 1 represents suspended particulate matter (PM 10) and the respirable (PM 2.5) particulate matter were measured in sites mainly mixing department, boiler and plant area and average value was taken for comparison with national and international standard

values. Both average RPM and SPM values in rubber industries are much higher than standard values. Besides temperature in boiler area (40°C) and humidity in mixing area (89%) were recorded maximum values in comparison to office area (26°C) and (58%) respectively.

Table 2: Demographic pattern of Rubber industry workers and control group

Socio-demographic Characteristics		Rubber industry workers(n=170)		Control(n=50)	
		No. of participants	Percentage	No. of participants	Percentage
Age in Years	20- 35Years	77	45.29	28	56
	≥36 years	93	54.70	22	44
Department	Factory Site	88	51.76	-	-
	Office	56	32.94	-	-
	Mixing	26	15.29	-	-
Type of work	Rubber industry workers	170	100	-	-
	Student	-	-	8	16
	Driver	-	-	3	6
	Lab Technician	-	-	7	14
	Office workers	-	-	23	46
	Shopkeepers	-	-	9	18
Year of Exposure	1-5 Years	85	50	-	-
	6-10 Years	42	24.70	-	-
	11-20 Years	43	25.29	-	-

Smoking Habit	Smokers	86	59.2	36	72
	Non-smokers	84	40.8	14	28
Shifting duty	Shift workers	60	35.29	-	-
	Non shift workers	110	64.70	-	-
Alcohol Intake	Yes	115	67.64	12	24
	No	55	32.35	38	76

Table 2 represents the demographic pattern of rubber industry workers and the control group. It was observed that 45.29% of workers were from the lower age group (20-35 years), and 54.7% were taken from the higher age group (≥ 36 years) compared to the control (56% and 44%, respectively). Besides, 15.29% of workers were taken from the mixing department, 51.76% from the production unit and 32.94% from the office staff of rubber industries. Among control group workers, 16% were taken from the student mass, 46% from office workers in schools and colleges, 14% from lab

technicians, 18% from shopkeepers and 6% were drivers. Depending on the year of exposure, 50% of rubber industry workers have 1-5 years of working experience, 24.7% have 6-10 years of experience, and 25.29% of workers have 11-20 years of working experience. 59.2% of these industry workers were smokers compared to 72% of smokers in the control group. 35.29% of workers perform shifting duty compared to non-shift workers. Along with that 67.64% of workers consume alcohol on daily basis.

Table 3: Comparison of physical and biochemical parameters between Rubber industry workers and Control group

Parameters	Rubber industry workers (n=170)	Control (n=50)	P value
Age (years)	38.88 \pm 11.650	37.48 \pm 11.555	0.46
Height (cm)	161.27 \pm 8.709	163.20 \pm 6.701	0.099
Weight (kg)	65.56 \pm 12.271	62.22 \pm 6.780	0.014*
BMI	25.25 \pm 4.643	23.36 \pm 2.051	0.0001****
Bilirubin total (mg/dl)	0.80 \pm 0.203	0.68 \pm 0.118	0.0001****
Bilirubin direct (mg/dl)	0.21 \pm 0.054	0.19 \pm 0.031	0.002**
Bilirubin indirect (mg/dl)	0.59 \pm 0.161	0.54 \pm 0.088	0.030*
Total protein (g/dl)	7.52 \pm 0.210	7.62 \pm 0.168	0.0001****
Albumin (g/dl)	4.69 \pm 0.164	4.82 \pm 0.164	0.0001****
Globulin (g/dl)	2.83 \pm 0.127	2.79 \pm 0.121	0.085
AG ratio	1.66 \pm 0.091	1.72 \pm 0.104	0.0001****
SGPT/ALT (U/L)	42.09 \pm 21.528	29.18 \pm 4.193	0.0001****
SGOT/AST (U/L)	35.22 \pm 15.010	28.08 \pm 5.816	0.0001****
ALP (U/L)	105.65 \pm 10.593	102.78 \pm 5.694	0.013*
GGT (U/L)	20.934 \pm 8.000	18.944 \pm 4.095	0.020*
R ratio (ALT/ALP)	1.44 \pm 0.630	1.05 \pm 0.162	0.0001****
Random Sugar (mg/dl)	101.13 \pm 42.162	93.48 \pm 15.39	0.05*
Creatinine (mg/dl)	1.0434 \pm 0.153	0.96 \pm 0.13	0.0001****
C-Reactive Protein (mg/L)	3.24 \pm 1.78	1.67 \pm 0.65	0.0001****

P<0.05-*, P<0.01-**, P<0.0001****

Table 3 represents physical, liver function and renal function parameters of rubber industry workers and control group. Among physical parameters body weight and BMI values are significantly higher ($p < 0.01-0.0001$) in rubber workers compared to the control group. Among liver function parameters ALT, AST, ALP and GGT values are significantly higher in rubber industry workers than control group. Besides total bilirubin, direct and

indirect bilirubin values show significantly higher values compared to control. In contrast, total protein and albumin level decreases significantly ($p < 0.0001$) compared to control. Besides random blood sugar level, serum creatinine and C-reactive protein (CRP) values are significantly higher in rubber industry workers indicating stress on hepatic and renal function among rubber industry workers.

Table 4: Comparison of physical and biochemical parameters between high and low age group Rubber industry workers

Parameters	Low age (n=77)	High age (n=93)	P value
BMI	24.52±4.624	25.859±4.597	0.061
Bilirubin total (mg/dl)	0.797±0.125	0.804±0.250	0.829
Bilirubin direct (mg/dl)	0.214±0.052	0.209±0.056	0.578
Bilirubin indirect (mg/dl)	0.583±0.092	0.595±0.202	0.649
Total protein (g/dl)	7.585±0.202	7.458±0.200	0.0001****
Albumin (g/dl)	4.739±0.152	4.644±0.161	0.0001****
Globulin (g/dl)	2.8494±0.146	2.814±0.107	0.081
AG ratio	1.668±0.102	1.652±0.0803	0.247
SGPT/ALT (U/L)	47.44±26.303	37.66±15.362	0.005**
SGOT/AST (U/L)	37.95±17.942	32.97±11.686	0.038**
ALP (U/L)	108.13±10.014	103.59±10.671	0.005**
GGT (U/L)	22.749±9.323	19.430±6.387	0.009**
R ratio (ALT/ALP)	1.577±0.757	1.3236±0.476	0.005**
Random Sugar (mg/dl)	103.25±41.804	99.38±42.602	0.553
Creatinine (mg/dl)	1.029±0.161	1.055±0.146	0.264
C-Reactive Protein (mg/L)	3.486±2.154	3.277±1.626	0.474

P<0.01-**, P<0.0001****

Table 4 represents mean and SD values of different biochemical parameters among higher and lower age group rubber industry workers. Total protein, albumin and hepatic enzymes (ALT, AST, ALP, GGT) are significantly higher in higher age group rubber

workers than lower age group. Accordingly, R ratio is also higher in higher age group workers than lower age group indicating metabolic alteration with age. than lower age group indicating metabolic alteration with age.

Table 5: Correlation between biochemical parameters and age, BMI, year of exposure, R ratio and CRP

Parameters	Age	BMI	Year of exposure	R ratio (ALT/ALP)	CRP
Bilirubin total (mg/dl)	0.082	-0.115	-0.096	0.440**	0.124
Bilirubin direct (mg/dl)	0.023	0.052	-0.155*	0.506**	0.177*
Bilirubin indirect (mg/dl)	0.095	0.127	0.069	0.384**	0.097
Total protein (g/dl)	-0.340**	0.066	-0.023	0.172*	0.097
Albumin (g/dl)	-0.339**	-0.045	-0.045	0.131	0.078
Globulin (g/dl)	-0.136	0.148	0.014	0.106	0.053
AG ratio	-0.125	-0.156*	-0.047	-0.002	0.004
SGPT/ALT (U/L)	-0.198**	0.116	-0.189*	0.984**	0.520**
SGOT/AST (U/L)	-0.142	0.116	-0.205**	0.955**	0.506**
ALP (U/L)	-0.252**	0.181*	-0.075	0.412**	0.166*
GGT (U/L)	-0.181*	0.119	-0.131	0.804**	0.375**
Random Sugar (mg/dl)	0.013	0.129	0.160*	-0.055	0.123
Creatinine (mg/dl)	0.124	-0.030	0.031	-0.090	0.028

P<0.05-*, P<0.01-**

Table 5 represents the correlation of biochemical parameters with age, BMI, year of exposure, R ratio, and CRP. A significant negative correlation was found between total protein, albumin, and liver enzymes (SGPT, SGOT, ALP, and GGT) with age. However, BMI showed a significant positive correlation with ALP and a negative correlation with the A/G ratio. Significant negative correlation was found between years of

exposure and direct bilirubin, SGPT, and SGOT, indicating possible chronic effects of exposure on liver function. Whereas strong positive correlations of R with SGPT, SGOT, ALP, GGT, and total bilirubin has been found indicating hepatocellular injury. A strong positive correlation of CRP with liver enzymes and direct bilirubin, indicating stress related inflammatory reaction among rubber industry workers.

Table 6: Comparison of biochemical parameters between high and normal BMI group of Rubber industry workers

Parameters	Normal BMI (n=90) (11.9-24.9)	High BMI (n=80) (25-29.9)	P value
Bilirubin total (mg/dl)	0.775±0.123	0.831±0.263	0.071
Bilirubin direct (mg/dl)	0.2070±0.046	0.216±0.061	0.278
Bilirubin indirect (mg/dl)	0.568±0.091	0.615±0.213	0.057
Total protein (g/dl)	7.494±0.188	7.541±0.232	0.141
Albumin (g/dl)	4.686±0.159	4.689±0.170	0.903
Globulin (g/dl)	2.810±0.121	2.852±0.131	0.030*
AG ratio	1.671±0.941	1.647±0.086	0.083
SGPT/ALT (U/L)	40.00±22.47	44.44±20.297	0.181
SGOT/AST (U/L)	33.58±15.198	37.08±14.669	0.130
ALP (U/L)	103.80±9.712	107.73±11.205	0.015*
GGT (U/L)	20.122±8.547	21.846±7.286	0.162
R ratio (ALT/ALP)	1.386±0.644	1.497±0.612	0.253
Random Sugar (mg/dl)	93.13±17.087	110.13±57.612	0.013*
Creatinine (mg/dl)	1.047±0.143	1.039±0.164	0.732
C-Reactive Protein (mg/L)	3.216±1.703	3.547±2.059	0.253

P<0.05-*

Table 6 represents comparison of liver and kidney function parameters between normal BMI and higher BMI group rubber industry workers. Significantly

higher serum globulin, ALP, and random blood sugar level has been observed with higher BMI group workers compared to the normal BMI group.

Table 7: Comparison of physical and biochemical parameters between daily alcohol consumer and occasional consumer

Parameters	Occasional consumer (n=55)	Daily consumer (n=115)	P value
BMI	24.329±3.995	25.693±4.879	0.073
Bilirubin total (mg/dl)	0.744±0.134	0.828±0.224	0.011*
Bilirubin direct (mg/dl)	0.1973±0.035	0.218±0.060	0.019*
Bilirubin indirect (mg/dl)	0.583±0.104	0.610±0.180	0.017*
Total protein (g/dl)	7.458±0.176	7.544±0.221	0.013*
Albumin (g/dl)	4.636±0.151	4.711±0.165	0.005**
Globulin (g/dl)	2.825±0.098	2.832±0.139	0.711
AG ratio	1.644±0.079	1.667±0.095	0.114
SGPT/ALT (U/L)	28.36±6.323	48.65±23.104	0.0001****
SGOT/AST (U/L)	26.13±4.944	39.57±16.229	0.0001****
ALP (U/L)	96.51±7.659	110.02±8.889	0.0001****
GGT (U/L)	16.527±3.366	23.041±8.702	0.0001****
R ratio (ALT/ALP)	1.080±0.232	1.609±0.687	0.0001****
Random Sugar (mg/dl)	105.69±55.286	98.95±34.243	0.331
Creatinine (mg/dl)	1.078±0.171	1.027±0.142	0.044*
C-Reactive Protein (mg/L)	3.118±1.346	3.493±2.083	0.225

P<0.05-*, P<0.01-**, P<0.0001****

Table 7 showed the comparison of various biochemical and liver enzyme parameters between occasional alcohol consumers and daily alcohol consumers of rubber industry workers. Daily consumers exhibit elevated serum concentrations of bilirubin total, bilirubin direct, bilirubin indirect total protein, albumin

and liver enzymes (SGPT, SGOT, ALP, and GGT), suggesting increased hepatic stress and early liver dysfunction among regular drinkers. R value also increased significantly but creatinine value slightly decreased in daily alcohol consumer compared to occasional consumer of alcohol.

Table 8: Comparison between biochemical parameters of workers of different departments of Rubber industry.

Parameters	Departments			F Value	P Value
	Office (N=56)	Production department (N=88)	Mixing department (N=26)		
Bilirubin total (mg/dl)	0.703±0.114	0.814±0.108	0.970±0.397	19.071	0.0001****
Bilirubin direct (mg/dl)	0.185±0.027	0.213±0.039	0.261±0.093	21.711	0.0001****
Bilirubin indirect (mg/dl)	0.518±0.091	0.601±0.083	0.071±0.327	15.020	0.0001****
Total protein (g/dl)	7.529±0.221	7.483±0.204	7.600±0.190	3.326	0.038*
Albumin (g/dl)	4.995±0.161	4.661±0.159	4.758±0.171	3.663	0.028*
Globulin (g/dl)	2.837±0.130	2.821±0.121	2.842±0.144	0.403	0.669
AG ratio	1.658±0.089	1.654±0.086	1.678±0.111	0.699	0.498
SGPT/ALT (U/L)	26.95±4.598	40.57±9.542	79.85±27.662	148.302	0.0001****
SGOT/AST (U/L)	22.79±2.661	35.10±5.819	62.42±16.539	228.981	0.0001****
ALP (U/L)	100.50±9.839	105.85±9.541	116.04±7.555	24.445	0.0001****
GGT (U/L)	16.048±2.929	20.557±4.477	32.731±12.065	70.846	0.0001****
R ratio (ALT/ALP)	0.989±0.166	1.404±0.288	2.522±0.810	139.269	0.0001****
Random Sugar (mg/dl)	108.80±58.794	97.22±26.233	97.85±42.662	1.392	0.251
Creatinine (mg/dl)	1.058±0.147	1.047±0.150	1.000±0.175	1.303	0.274
C-Reactive Protein (mg/L)	2.818±1.165	3.239±1.499	5.014±3.089	14.586	0.0001****

P<0.05-*, P <0.0001****

Table 8 represents comparison of mean and \pm SD values of biochemical parameters of different departments of the rubber industry. Mixing unit is most dusty and polluted area compared to production unit. Office area is comparatively less polluted according to environment report (table-1). It has been found that all the biochemical parameters are significantly increased from less dusty (office area) to dustier (production unit) and maximum increase has been found in most dusty

mixing department workers. But no significant changes in serum globulin, A-G ratio, random sugar and creatinine level have been observed with increase in exposure i.e. less dusty to dustier department. Significantly higher CRP value in mixing department compared to production and office unit indicate inflammatory reaction is associated with exposure to higher level of pollutants.

Table 9: Effect of smoking habit, year of exposure, BMI, shifting duty and alcohol consumption on the prevalence of SGOT and SGPT with odds ratio (OR) and 95% confidence interval (95% CI) among rubber industry workers

Group	No. Examined	High SGOT				High SGPT			
		No	%	OR	95% CI	No	%	OR	95% CI
Smoking habit									
Smoker	86	24	27.91	0.977	0.496-1.887	32	37.21	0.871	0.470-1.616
Non-Smoker	84	24	28.57	1		34	38.09	1	
Based on year of exposure									
11-20 years	43	9	20.93	0.539	0.227-1.277	11	25.58	0.425	0.190-0.953
6-10 years	42	11	26.19	0.722	0.317-1.645	17	40.48	0.841	0.397-1.780
1-5 years	85	28	32.94	1		38	44.70	1	
Based on BMI									
High BMI	80	26	32.5	1.488	0.761-2.911	37	46.25	1.810	0.970-3.376
Normal BMI	90	22	24.44	1		29	32.22	1	
Shifting duty									
Shift workers	60	30	50.00	5.111	2.5-10.448	36	60.00	4.000	2.056-7.782
Non-shift workers	110	18	16.36	1		30	27.27	1	
Daily intake of alcohol									
Daily consumer	115	65	56.52	70.20	9.386-525.024	47	40.87	18.316	4.254-78.864
Occasional consumer	55	1	1.81	1		2	3.64	1	

Table 9 represents the odds ratio and 95% CI of the elevated liver enzymes (SGPT and SGOT) by BMI, smoking habit, year of exposure, shifting pattern of duty and alcoholism. Workers with high BMI and involved in

shifting pattern of duty in rubber industry are more prone to prevalence of elevated liver enzyme (OR 1.48 to 5.11), indicates obesity and shifting pattern duty that can alter the metabolic pattern.

Table 10: Multiple logistic regression equation of prevalence of high SGOT and high SGPT among Rubber industry workers

Parameters	Coefficient	SE	P value	Adjusted OR	95% Confidence Interval	
					Lower	Upper
High SGPT						
Age	-0.026	0.021	0.217	0.975	0.936	1.015
BMI	0.021	0.043	0.631	1.021	0.938	1.111
Smoking habit	-0.407	0.414	0.325	0.665	0.296	1.497
Year of Exposure	-0.086	0.047	0.069	0.918	0.836	1.007
Alcoholism	-4.363	1.056	0.0001****	0.013	0.002	0.101
CRP	0.367	0.147	0.013*	1.443	1.081	1.926
High SGOT						
Age	-0.011	0.021	0.587	0.989	0.950	1.030
BMI	0.001	0.041	0.974	1.001	0.924	1.086
Smoking habit	-0.461	0.409	0.259	0.630	0.283	1.405
Year of Exposure	-0.067	0.048	0.163	0.935	0.851	1.028
Alcoholism	-3.746	1.052	0.0001****	0.024	0.003	0.186
CRP	0.357	0.127	0.005**	1.429	1.115	1.831

P<0.05-*, P<0.01-**, P <0.0001****

Table 10 provides logistic regression analysis of the prevalence of abnormal liver enzymes on the basis of age, BMI, smoking habit, year of exposure, alcoholism and CRP. The multivariate analysis indicated that

elevated serum concentrations of SGPT and SGOT are significantly (P=0.0001) correlated only with alcoholism and CRP (P=0.05, P=0.01).

Table 11: Percentage prevalence of abnormal hepatic enzyme levels among rubber industry workers and the control group

Parameters		Rubber industry workers		Control group	
		No	%	No	%
SGPT (ALT)	Abnormal	66	38.82%	5	10%
	Normal	104	61.18%	45	90%
SGOT (AST)	Abnormal	49	28.82%	3	6%
	Normal	121	71.18%	47	94%

Table 11 indicates the percentage prevalence of abnormal liver enzyme levels among the exposed and control group individuals. It was observed that 38.82% of rubber industry workers exhibited abnormal SGPT

value compared to the 10% control individuals. Similarly, an abnormal SGOT value was found in 28.82% of rubber industry workers, compared to 6% of control group individual.

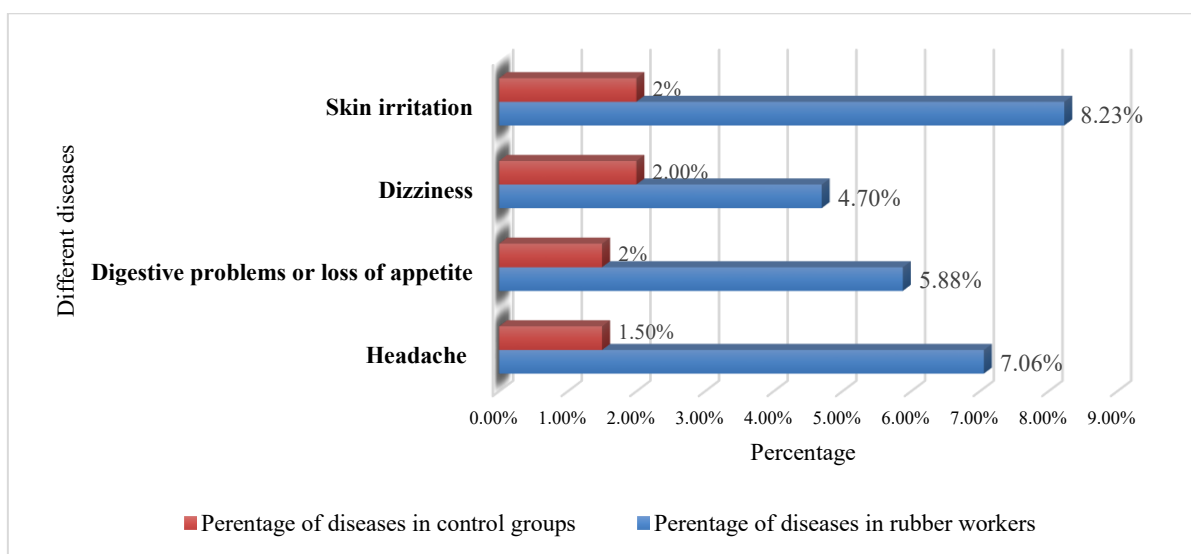


Fig. 1: Percentage of prevalence of different diseases among rubber industry workers

Fig 1 represents percent prevalence of headache, gastrointestinal problems, dizziness and skin irritation among rubber industry workers and control group workers.

DISCUSSION

In rubber manufacturing industry, there are multiple occupational exposure to dust and variety of volatile organic compounds (VOCs) such as benzene, toluene and xylene (Malaguarnera *et al.*, 2012; Soyinka *et al.*, 2007). Health hazards of these compounds are due to metabolic conversions to more hazardous substances in liver which may cause injuries to different organs including liver. Multiple factors can increase risk of hepatotoxicity including duration of exposure, obesity, drugs, genetic factors, alcoholism and without use of personal protective equipment's etc.

The present study revealed that all the liver enzymes (ALT, AST, ALP, GGT) of rubber industry workers along with R ratio are significantly higher in experimental group compared to the control group. These findings corroborate with the study of Hasani *et al.*, (2015) in Egypt. They found that workers occupationally exposed to organic solvents (mainly toluene, styrene and benzene) in furniture manufacturing unit, had higher liver enzyme parameters compared to control. ALT was increased with increasing duration of exposure. Although no such increase in ALT or AST was found in our study. But in our study R ratio (<2) increase significantly in exposed group (rubber workers) compared to control group indicating cholestatic injury. Again, Elghmry *et al.*, (2019) and Aminian *et al.*, (2007) found statistically insignificant difference in liver enzymes (ALT and AST) on exposure to organic solvent. The reason might be the levels of organic solvent that were not so far from the permissible limit of these solvents and use of protective equipment's might be the reason for this difference in results.

In the present study 33% rubber industry workers have higher total bilirubin value, 7.65% have higher direct bilirubin and 0.59% have higher indirect bilirubin value compared to control group (6%, 2% and 0% respectively). Similar observations have been reported by Katz, (1962) on rubber producing members. Airhomwanbor *et al.*, (2024); Gali R *et al.*, (2012); Nwanjo & Ojiako, (2007); Ogunneye *et al.*, (2014) also found significantly higher ($p < 0.05$) total and conjugated bilirubin level in gas factory and petrol station workers compared to control subjects. In a study by Døssing, (1986) in chemical plant workers reported that workers of this industry become jaundiced and showed hepatic necrosis due to occupational exposure to carbon disulphide, isopropane, toluene and acrylonitrile for 2-4 months. Hsiao *et al.*, (2009) found direct positive relation with dichlorobenzene and tetra-choloro ethane with

bilirubin level and lactate dehydrogenase. Our study also corroborate with this finding and rubber industry workers are also exposed to a variety of VOCs – benzene, toluene and xylene (Malaguarnera *et al.*, 2012; Soyinka *et al.*, 2007) and metabolic conversion of these compounds may cause organ injury including liver.

In our study, the environmental parameters of rubber industry highlight that PM10 and PM 2.5 are much higher than their permissible limit. Air pollution was associated with increased risk of non-alcoholic fatty liver disease and or cirrhosis in longitudinal studies (Li *et al.*, 2023; VoPham *et al.*, 2022; Ye *et al.*, 2023) which was reflected through elevated liver enzymes in our study. These exposures were associated with alternatives in circulating metabolome (Ran *et al.*, 2025) and proteome. Longitudinal studies demonstrated that exposure of residential blue and green spaces decreased risk for incident of metabolic associated steatotic liver disease (MASLD) or severe liver disease and protective effect was mediated by reduction in PM 2.5 and other air pollutants (Liu *et al.*, 2023; Ye *et al.*, 2023). Due to small size, PM2.5 particles can penetrate deep into the lungs and then pass into blood stream, allowing them to effect different organs like lung and liver (Chin *et al.*, 2022; Cicalese *et al.*, 2017). Particulate matter can induce oxidative stress and inflammation in liver cells which can contribute to development of liver disease and cancer (Cicalese *et al.*, 2017; Raun *et al.*, 2018). Inhaled pollutants such as polycyclic aromatic compounds (PAHs), NOx, and VOCs have been linked to liver dysfunction in both animal models and human studies (Becker *et al.*, 2023; Mizuta & Ozaki, 2008; Song *et al.*, 2011). These pollutants are capable of inducing genotoxic effects i.e, damage DNA and disrupt cellular repair mechanism, leading to cancer. Long term exposure to high PM 2.5 has been associated with an increased risk of liver inflammation, fibrosis and ultimately hepatocellular carcinoma (Lee *et al.*, 2019; Wu *et al.*, 2022).

Further studies have shown that PM 2.5 exposure impairs the liver's capacity to metabolize and clean toxins effectively, increasing susceptibility to diseases such as non-alcoholic fatty liver disease (NAFLD), non-alcoholic steatohepatitis (NASH), liver cirrhosis and ultimately hepatocellular carcinoma (HCC) (Chan *et al.*, 2020; Chen *et al.*, 2021; Jian *et al.*, 2018; Xu *et al.*, 2019).

Higher liver enzymes (ALT, AST, ALP, GGT) level of our study can also be associated with non-alcoholic fatty liver disease which is characterized by excessive hepatic fat accumulation and is linked to metabolic abnormalities like obesity and insulin resistance. In the present study crude odds ratio values indicates BMI as a risk factor for prevalence of elevated

liver enzymes (ALT and AST) and significantly higher random blood sugar level with high BMI ($\geq 24.9 \text{ kg/m}^2$) was observed. Besides, rubber industry workers had significantly higher blood sugar level (i. e. insulin resistance) compared to control group. This indicates metabolic dysregulation among these groups of workers which can cause potentially reversible stages of liver damage (steatosis and steatohepatitis) to more severe irreversible stages including fibrosis and cirrhosis if left untreated or if environmental factors like PM 2.5, VOCs and other chemical exposure cannot be regulated. Biologically, the mechanisms through which air pollution can contribute liver carcinogenesis are well supported by current research. PM2.5 in air induce oxidative stress, chronic inflammation and genotoxicity in liver cells. These processes can damage functional liver cells, leading to DNA mutations, cell death and increased risk of carcinogenesis. In our study chronic inflammatory effect has been found with the evident of significant rise of c reactive proteins (CRP) levels in rubber workers compared to controls.

Crude OR values of present study also indicate shifting pattern of duty and alcoholic intake are also important risk factor for elevated liver enzymes (AST, ALT) (Anisimov *et al.*, 2004 and Kettner *et al.*, 2016) found association of shift work with non-alcoholic fatty liver disease (NAFLD) which corroborate our study but Balakrishnan *et al.*, (2017) did not observed any such association in their study. Circadian disruption has been proved related to hepatocellular carcinoma in rodents through induction of NAFLD (Kettner *et al.*, 2016) but no conclusive result in human has been found. Besides excessive alcoholic intake may induce alcoholic liver disease initiated by simple steatosis, which may progress to more severe pathologies (Williams *et al.*, 2014). In addition to alcohol intake metabolic disorders like obesity (high BMI) and diabetes (high blood sugar level) are increasingly recognized as significant risk factors like liver cancer especially in developed countries (Chen *et al.*, 2021). These findings are similar to our observation. Although in our study multiple logistic regression equation for prevalence of high ALT, and AST revealed significant association with alcoholism and C-reactive protein (CRP) level only.

Liver injury is termed hepatocellular injury when $R \geq 5$, cholestatic when $R \geq 2$ and mixed when $R \geq 2-5$ (Shaikh *et al.*, 2024). In the present study R value is <2 when compared with non-exposed control group. Department wise study indicated that R value is between >2 and <5 in mixing department (most polluted part of rubber industry) and <2 in production department as well as office, indicating tendency of liver injury pattern from cholestatic (production department) to mixed (hepatocellular as well as cholestatic) biochemical pattern (Robles-Diaz *et al.*, 2014).

In the present study, rubber industry workers showed significantly elevated pattern AST, ALT, ALP, and GGT values from less polluted (Office area) to highly polluted (mixing) department. Similarly, Cotrim *et al.*, (2005) observed AST and GGT values among Brazilian petrochemical workers in the administrative part of industry even after controlling alcohol consumption, obesity and history of hepatitis (Carvalho *et al.*, 2006). It was also found that 72% petrochemical workers with a diagnosis of NAFLD did not have any insulin resistance suggesting VOC exposure itself induce accumulation of fat in the liver (Cotrim *et al.*, 2005). Abnormal liver enzymes and histology subsided in these patients when they are removed from exposure i.e, outside industrial area (Cotrim *et al.*, 1999).

Besides, Ho *et al.*, (1991) observed in a study with workers exposed to Vinyl chloride that raising the serum ALT levels was the first enzymatic abnormality to occur, followed by abnormalities in GGT levels. Their study demonstrated that concomitant raised level of enzymes, GGT, ALT, could be useful as an early detector of liver abnormalities before irreversible lesions might develop. Reversal of enzymatic levels was also observed after removal from exposure. Cotrim *et al.*, (1999) also observed non-alcoholic steatohepatitis (NASH) on exposure to petrochemical products in Bahia.

A cross-sectional study by Barberino *et al.*, (2005) carried out in 1997 /98 in oil refinery workers of urban Salvador and revealed that prevalence of liver abnormalities (mainly ALT and GGT) was 3.56 times greater (95% CI, 1.99-6.38) than office workers. This risk was adjusted for other relevant co-variables – obesity, physical exercise, smoking and alcohol intake. Our study also corroborates with this finding and found that prevalence of liver enzyme abnormality (ALT and AST levels) was 1.488 times to 70 times more prevalent in rubber workers compared to control. Burns *et al.*, 1996 in a study with male petrochemical workers, observed that BMI and alcohol consumption had association with level of enzyme activities (ALT, AST and GGT). Burns *et al.*, (1996); Fernández-D'Pool & Oroño-Osorio, (2001) also indicated that obesity, alcohol consumption, black race, age and insulin resistance are the principal factors responsible for liver enzyme alterations among petrochemical workers.

Again, serum albumin and A/G ratio values decreased significantly when compared to control. This might be due to toxicants exposure in workplace and smoking habit (De Smedt *et al.*, 2014; Thier *et al.*, 2001).

In our study creatinine level is significantly higher in experimental group compared to control group. Similar result has been observed by Bin-Mefrij *et al.*, (2017) indicated that exposure to benzene causes an increase in serum creatinine and urea. Besides D'Andrea & Reddy, (2014); Neghab *et al.*, (2015) also found

similar result and concluded that benzene exposure might be the cause of elevated level of creatinine in exposed group compared to non-exposed group. No significant relation has been found between age and creatinine level in our study which corroborate with the study of El-Kheir El-Awad *et al.*, (2016). Again, present study indicted no significant association between year of exposure and smoking habit with creatinine levels among benzene exposure group for 6-10 years but Bin-Mefrij *et al.*, (2017) reported that more than 5 years of benzene exposed gasoline workers had elevated creatinine level compared to unexposed.

CONCLUSION

The study concluded that exposure to rubber dust and mixture of hydrocarbons have extensive effects on liver function parameters, creatinine level and random blood sugar level to some extent as well as CRP, therefore evaluation of transaminase in rubber industry workers might be beneficial for early detection of hepatocellular injuries.

Environmental monitoring revealed high level of dust, fumes, temperature and toxic volatile organic components along with life style factors- BMI, alcoholism, shifting pattern of duty might be the reason for abnormalities of liver function parameters. Besides, safety measures of rubber factories was insufficient and workers did not receive any pre-employment training for safe work practice and use of protective measures.

So, suitable engineering and environmental controls to occupational exposure to chemicals, heat, fumes and dust must be implemented to minimise the exposure. Regular environmental monitoring, health education and awareness programme, periodic medical examinations should be done for workers of this industry to protect the liver health and decrease the incidence of cancer of workers of this industry and society will be benefitted and economic growth will be continued.

LIMITATIONS OF THIS STUDY

This is a cross-sectional study and the causality can only be an assumption and personal exposure to environmental toxins and pollutants cannot be measured. So, study with large sample size for this population will pin point the causality factors related to liver function parameters.

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