

Original Article

Work Environments and Exposure to Hazardous Substances in Korean Tire Manufacturing

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Objectives: The purpose of this study is to evaluate the tire manufacturing work environments extensively and to identify workers' exposure to hazardous substances in various work processes.

Methods: Personal air sampling was conducted to measure polycyclic aromatic hydrocarbons, carbon disulfide, 1,3-butadiene, styrene, methyl isobutyl ketone, methylcyclohexane, formaldehyde, sulfur dioxide, and rubber fume in tire manufacturing plants using the National Institute for Occupational Safety Health Manual of Analytical Methods. Noise, carbon monoxide, and heat stress exposure were evaluated using direct reading instruments. Past concentrations of rubber fume were assessed using regression analysis of total particulate data from 2003 to 2007, after identifying the correlation between the concentration of total particulate and rubber fume.

Results: Workers were exposed to rubber fume that exceeded 0.6 mg/m³, the maximum exposure limit of the UK, in curing and production management processes. Forty-seven percent of workers were exposed to noise levels exceeding 85 dBA. Workers in the production management process were exposed to 28.1°C (wet bulb globe temperature value, WBGT value) even when the outdoor atmosphere was 2.7°C (WBGT value). Exposures to other substances were below the limit of detection or under a tenth of the threshold limit values given by the American Conference of Governmental Industrial Hygienists.

Conclusion: To better classify exposure groups and to improve work environments, examining closely at rubber fume components and temperature as risk indicators in tire manufacturing is recommended.

Key Words: Rubber, Occupational exposure, Aerosols, Carbon disulfide

Introduction

Seven cases of sudden cardiac death and five cases of cancer occurred among the employees of a particular Korean tire manufacturer between May 2006 and September 2007, leading

to concerns about the work environments involved and a need for research into plant practices.

Related studies of tire manufacturing industry and rubber industry have been published elsewhere. For example, the US Occupational Safety and Health Administration warned of excessive cancer mortality in the rubber industry, including tire manufacturing in 1980 [1]. The International Agency for Research on Cancer also designated "the rubber industry" as carcinogenic (Group 1) because "workers employed in the industry before 1950 have a high risk of bladder cancer, probably associated with exposure to aromatic amines. Leukaemias had been associated with exposure to solvents and with employment in back processing, tire curing, synthetic rubber produc-

Received: August 22, 2011, **Revised:** March 5, 2012

Accepted: March 6, 2012, **Available online:** June 8, 2012

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tion, and vulcanization. Excess mortality from lymphomas had been noted among workers exposed to solvents in such departments as footwear and in tire plants. Other cancers, including those of the lung, renal tract, stomach, pancreas, esophagus, liver, skin, colon, larynx, and brain, had been reported as occurring in excess in various product areas and departments.” They concluded, however, that no consistent excess of any of these cancers was seen across the various studies [2].

Other studies of cardiovascular disease rates in the rubber/tire manufacturing industry had been undertaken, with inconsistent results. Wingren [3] found an excessive mortality rate among workers who had worked for less than 6 months in Swedish tire manufacturing. The US National Institute for Occupational Safety and Health carried out a case-control study of tire manufacturing, but did not find a link between heat conditions and myocardial infarction [4]. Wilcosky and Tyroler [5] could not prove that organic solvents were the cause of ischemic heart failure in rubber industry workers.

Tire manufacturing and rubber industry environments have been monitored across several European countries. The target substances for this air monitoring were n-nitrosamine, inhalable aerosol, cyclohexane-soluble matter, and specific solvents [6]. Rubber fume occur in the mixing and milling of natural rubber or synthetic polymers combined with chemicals, and in the processes which convert the resulting blends into finished products [7]. No-observed-adverse-effect-level of rubber fumes has not been identified, but the UK assigns maximum exposure limits of rubber fume as 0.6 mg/m³ cyclohexane soluble material [7]. Although a specific carcinogen has not been

clearly identified, rubber fume has been shown to contain small variable amounts of mutagenic substances [8].

The work environments in the tire manufacturing plants are monitored by employers in order to meet Korean regulations every 6 months. The employer in this case study had monitored the total particulates, organic solvent, and noise levels. All of these values were low, compared to the Korean Occupational Exposure Levels.

Several countries (Sweden, UK, Poland, and Germany) initiated prospective cohort studies to address the risk in the contemporary rubber industry. The improved exposure assessment for prospective cohort studies and exposure control in the Rubber Manufacturing Industry was initiated with the European Union [6]. The health risk in the rubber industry is still controversial. An outbreak of sudden cardiac death and cancer cases in a tire manufacturing initiated the concern on the work environment in the Korean tire manufacturing industry for the first time. This epidemiological study was designed at the request of the Ministry of Labor in order to investigate the excessive mortality rate and work environments closely in the tire manufacturing plants. Our purpose is to evaluate the work environment extensively in tire manufacturing plants and to identify process workers' exposure to hazardous substances.

Materials and Methods

Study object

The target tire manufacturing company has two plants (plant A and plant B). This company produces various sizes of pas-

Table 1. Description of processes in tire manufacturing plants

Process	Description
Compounding, Banbury mixing	Vulcanizing agents and accelerators in the form of powders are weighed and fed into a Banbury mixer. Carbon black is fed by hopper. All ingredients are input on the second floor and mixed in the Banbury. The temperature in the mixer is 150-190°C. The “Q rubbers” sheets are coated by the releasing agent. The cement is made in a separate building. The main organic solvent of cement is methylcyclohexane.
Extrusion	Q rubbers are carried in hot screws and cut in the shapes of tread and side wheels. The temperature of the outlet is 125°C. Cement is used to bind and correct the rubbers. Pigments are used to print letters on treads.
Calendering	The softened rubber is applied to the textile or steel cord to make ply stock of the tire. The temperature is 75-95°C.
Bead building	The rubber is applied in a bead wire to make beads.
Tire building	The green tire is assembled with tread, beads, ply stock, sidewalls, and other component on a drum. The tire building operation area is next to the curing area.
Curing	The green tire is placed in the mold and vulcanized under heat (150-180°C) and pressure. The operation time of a mold is about 8-12 minutes. Approximately 200 molds are placed in the unit plant. The atmosphere in a curing operation is hot and humid. There is no air exhaust system.
Production management	Workers in production management change and clean the molds and bladders in the curing operation.
Facility maintenance	Workers in facility maintenance fix any problems occurring during the operation of the plant.

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