Biomonitoring of co-exposure to mixture of organic solvents and noise on hearing among industry workers

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Abstract

Occupational exposure to noise and mixtures of organic solvents affects many workers in different sectors. The combined exposure to solvents and noise can negatively affect the auditory system. The aim of this study is to evaluate the effects of the combined exposure to noise and solvents on hearing in workers. Our study included 70 workers; we subdivided them into 3 groups according to their exposure status. The first group contained workers exposed only to noise, the second group contained workers exposed to solvents and the third group included workers exposed to both noise and mixture solvents. The results show that the workers are exposed to a both ototoxic substances and moderate to high level noise. We deduce that the combined exposure to noise and solvents has a synergistic interaction which leads to an adverse interactive effect on hearing. Therefore, a suitable hearing protection program is advised that would contain short-interval audiometric examinations and efficient hearing protectors.

Keywords: **Solvents, noise, co-exposure, synergistic interaction, hearing loss.**

Résumé

L'exposition professionnelle au bruit et aux solvants pures ou mélangés concerne de nombreux travailleurs dans différents secteurs de travail. L'effet des solvants organiques combiné à celui du bruit pourrait avoir un rôle synergique et compromettre ainsi la fonction auditive. Le but de cette étude est d'évaluer l'effet de la co-exposition au bruit et aux solvants sur la perte auditive des travailleurs d'une entreprise de fabrication et de montage de meubles. Cette étude a intéressé 70 salariés, divisés en 3 groupes selon leurs activités. Le premier groupe est formé de salariés exposés uniquement au bruit. Le deuxième groupe est formé de salariés exposés aux solvants ; et le troisième est formé de salariés exposés à la fois au bruit et aux

solvants. Il ressort de cette étude que les travailleurs sont exposés à la fois à des substances ototoxiques et à des niveaux sonores modérés à élever. Nous en déduisons que l'exposition combinée au bruit et aux solvants pourrait avoir une interaction synergique qui conduit à un effet interactif néfaste sur l'audition. Toutefois, un programme de protection auditive appropriée est conseillé par des explorations audiométriques à court terme et le port des équipements de protection individuelle.

Mots-clés : Solvants, bruit, Co-exposition, effet synergétique, perte d'audition.

1. Introduction

Hearing loss is a widespread occupational impairment among industrial workers. The exposure to intense noise is the most common cause of hearing impairment in employees (Saraei et al, 2021; Sheppard, 2020; Wang et al. 2020; Mirza et al. 2018). Several factors are strongly associated with hearing loss in workers such as age, heredity, ototoxic drugs (Rizk, 2020) and exposure to ototoxic substances in working environments (Hemmativaghef et al. 2020).

Not only workers are exposed to noise, but also, they are exposed to chemicals such as mixtures of organic solvents. Organic solvents are used in different industries as major components of adhesives, fuels, additives, etc…. Solvent toxicity can result from accidental inhalation, ingestion and skin absorption (Pleban et al, 2017). As a result, organic solvents achieve the inner ear through the blood stream. Several evaluations suggested that occupational to solvents such as toluene, styrene, xylene, and ethyl benzene have a toxic effect on the auditory system: organ of Corti, the middle-ear reflex (Venet et al. 2011; Wathier et al. 2016; Rosati et al. 2020).

The relationship between occupational co-exposure to organic mixtures solvents and noise was the subject of different researches. According to the results of studies among animals, co-exposure to noise and mixtures of organic solvents increases the risk of hearing impairment (Campo et al. 2009). Human's studies reported that combined exposure to noise and organic solvent has a synergistic effect which induces hearing loss (Fetoni et al. 2016; Hormozi et al. 2017). In addition, similar studies have verified that the exposure to organic solvents combined with noise, are associated with hearing loss among workers (Kim et al. 2005; Mohammadi et al. 2010; Nakhooda et al. 2019).

Our research was carried out in a Tunisian furniture manufacturing company. The choice for this company was

justified by the presence of two harmful effects represented mainly by the exposure to various solvents (coming from products of painting, adhesives) and noise (coming from various machines used in this company).

The goal of this paper is to evaluate the co-exposure to noise and mixtures of organic solvent in furniture manufacturing company.

2. Methodology

A total of 70 workers were selected among the 90 employees in a furniture manufacturing company, aged 20-59 years.

The evaluation of the exposure to solvents was based on dynamic taking away of the samples of ambient air carried out in the company by trapping of the pollutants on an adsorbent (activated carbon) using an individual pump. Sampling pumps used were calibrated for a flow 0,2 l/min. The adsorbing tube was placed on the level of respiratory tracts of the workers. All the air samples were sent to Laboratory of Toxicology, Ergonomics and Professional Environment - Faculty of Medicine of Tunis for analysis. After desorption by the CS2, the samples were analyzed by a chromatography in gas phase equipped with a detector FID. The level of exposure to mixed organic solvents was determined by the following equation (1):

$$E_m = C_1/L_1 + C_2/L_2 + C_3/L_3 + \ldots\ldots\ldots + C_n/L_n$$

Where

E_m: is the equivalent exposure for the mixture of solvents organic.

$C_1 \ldots C_n$: represents concentrations of the respective substances in environment air.

$L1 \ldots\ldots L_n$: is the exposure limit for organic solvents.

Noise was measured at different productive areas in furniture manufacturing company with a sound level meter (Brüel & Kjaer 2238) which allowed us to monitor noise levels at the different workplaces.

Each worker was monitored for 8 hours. The data were recorded during the work.

3. Results

a) Noise exposure surveillance

The noise levels (at different measurement locations)

monitoring results tabulated below (Table 1) were carried out in accordance with European standards.

Table. 1: Monitoring noise levels in different workstations

Workplace	Leq (dB(A))	European standards
Stapler Sitting	92	
Seat stapling	92	
Plate staple	90	
Stapler on wood	90	
Fun With Glue	88	
Finishing	82	
Office finishing	75	85(dB(A))

The findings of the study showed that the noise level values in furniture manufacturing company varied from 75 to 92 dB (A). Generally, the average noise levels in the company were higher than the level of 85 dB(A) recommended by the European Standards. So, the present findings showed that workers were experienced impulsive noise from different machines used.

We noted that no workers of furniture manufacturing company were wearing personal protection equipment (PPE).

b) Organic solvent exposure

Workers in a furniture manufacturing company are exposed to a mixture of organic solvent. This exposure is about 8 hours / day, and about 40 hours / week. The concentrations of organic solvents in the company were demonstrated in Table 2.

Table. 2: concentration of organic solvents in manufacturing and assembly of furniture Company

Organic solvents(ppm)	Manual collage of furniture	Finishing	Spray collage	European standard (ppm)
Toluene	314	165.2	16.4	50
Hexane	219.1	ND	ND	50
Cyclohexane	153.5	ND	5.8	300
Perchlorethylene	ND	35.8	ND	25
Ethyl-acetate	877	ND	ND	400
Methyl-ethyl-cetone	137.2	ND	ND	200

ND: not determinent

Based on Table 2, the result obtained showed that the mean measured concentrations in all units studied are higher than the European standards for the solvents tested (toluene, ethyl acetate, and hexane). In contrast, the results showed that the mean concentration of cyclohexane (153.5 ppm) and methylethylcetone (137.2 ppm) is below European standards.

During our visit to a furniture manufacturing company, we noted that workers wear a uniform, but they don't use gloves and

a mask. We noted a lack of ventilation in the workshops, especially in fun with glue workplace.

c) Co-exposure to solvents and noise

Table 3 summarizes the results of co-exposure to solvents and noise.

Table 3: Solvent concentration and noise level in work-places

Workplaces	Noise level (dB(A))	Solvent concentration (ppm)
Stapler on wood	90	14.08
Finishing	82	4.73
Stapler Sitting	92	0.35
Seat stapling	92	0.35
Plate staple	90	0.35
Fun with glue	88	0.35
Office finiching	75	0.35

Sound pressure level in the workplace, ranged from 75 to 90 dB(A). As a result, 5 workplaces among 7 showed a noise level in excess of 85 dB(A). The average of equivalent exposure (Em) recorded in different productive areas ranged from 14.08 to 0.35 ppm. So, Em in the first and the second workplaces was above the limit (According to American Conference of Governmental Industrial Hygienists ACGIH, Em should not exceed 1).

This study revealed that workers were exposed to both excessive noise level and mixtures of organic solvent. So, Co-exposure to noise and solvents has a synergistic interaction which leads to hearing loss.

Our study in furniture manufacturing company showed many deficiencies in work conditions. We noted that workers performing different activities in the same work area at the same moment. Then, we noted the lack of break room (employees eat in offices, locker rooms, workshops). Furthermore, furniture manufacturing company was characterized by inadequate ventilation. Remember that all workers wear uniforms, but not personal protection equipment (PPE), neither mask, nor gloves during work.

4. Discussion

The ototoxicity of organic solvent and their interaction with noise is a common problem in occupational impairments. The finding of this research revealed that occupational exposure both to noise (ranged from 75 to 90 dB(A)) and organic solvents (ranged from 14.08 to 0.35 ppm) leads to a synergistic interaction among furniture manufacturing company workers.

Unlu et al. (2014) reported that this synergistic interaction exacerbates hearing loss in workers. So, combined exposure to mixed solvents and noise induces the damage of sensory hair cells of the cochlea and cell death (Chen and Henderson, 2009). Our results are similar to other studies among workers exposed to moderate or high levels of organic solvents (Sliwinska-Kowalska et al. 2004; Kim et al. 2005; Chang et al. 2009; Mohammadi et al. 2010; Mhamdi et al. 2012). Not only the interactive effect leads to hearing loss but also, the combined effects of noise and solvents can interact to alter brain activity (Wong et al, 2016). Besides, occupational exposure to noise or a mixture of organic solvents may be associated with the prevalence of high blood pressure in workers (Attarchi et al. 2013).

The findings also revealed that organic solvents remain a harmful factor for workers. The toxicity of solvent increase with the working conditions, especially poor ventilation (when all doors are closed in winter). In addition, this high result is influenced by climatic conditions of sampling such as poor ventilation, high evaporation of solvent in summer. Furthermore, Zeise et al, (2020) reported that low daily exposure to toluene in women seems to be associated with a reduction of fecundity and pregnancy. The findings of the study collide with the results of different studies in Tunisia for example, researches of Aissa (2006), Elwafi (2007), Mhamdi et al, (2012).

On the other hand, workers were experienced impulsive noise from different machines. Consequently, high level of noise threatens the health of workers: stress, hypertension, headache, loss of sleep/insomnia, and hearing problems (Alkaabi, 2017; Fu et al. 2017; De Souza et al. 2015; Davies and Van Kamp, 2012). Noise remains the most harmful occupational factor for hearing loss. The high noise levels would expose concerned workers to hearing damage risks, which requires adequate and immediate preventive intervention. The high noise levels in our study are consistent with the results of different studies in Tunisia for example, researches of Nassiri (2006), Zahouani (2005) and Jmai (2008).

In order to improve working conditions in furniture manufacturing company, we propose the following recommendations:

- Physical separation in the workplaces
- Improving the general ventilation system and setting up a suction system

- Use personal protection equipment, mask and gloves.
- Implementation of food hygiene regulations.

5. Conclusion

The present findings showed that the workers are exposed to a both ototoxic substances and moderate to high levels of noise. In order to protect workers of this company a suitable hearing protection program is advised. Then, a need of audiometric and bio-toxicological monitoring is necessary to be installed.

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6. References

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