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THE EFFECT OF ORGANIC SOLVENTS ON THE PERIPHERAL NERVOUS SYSTEM IN EXPOSED WORKERS

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Summary. *An analysis of the working conditions in the cartridge, drying and top-coat sections of paint and lacquer industry has shown an above permitted level of white spirit and toluene. The exposed group comprised 100 workers occupationally exposed to these noxae, whilst the control group included 55 workers who had never been exposed to the same agents. The exposed workers more frequently complained of numbness of the arm and leg, cramps in the shoulder and knee, and weakness in the arm and leg than did the control workers. The electromyoneurographic examination of the median and peroneal nerve showed that a decrease in motor and sensitive conduction velocity was more significant in the exposed group compared to the control. The reduction in motor and sensitive conduction velocity was in correlation with the length of exposure to the noxae. Terminal latency of the median and peroneal nerve was significantly longer in the exposed group compared to the control, with an increase proportional to the exposure length. The exposed workers had a significantly longer time of response to acoustic and visual stimuli. The results of the study suggest neurotoxic effects of the noxae detected in paint and lacquer industry.*

Key words: *Organic solvents, median nerve, peroneal nerve, elecroneurographic examinations*

Introduction

Organic solvents are chemically heterogeneous compounds that all share the property of dissolving fats, oils, resin, cellulose accetate and cellulae nitrate. This common feature makes them widely used in industry, in particular in paint and lacquer production, manufacture of pesticides, plastics, explosives, rubber, cellulose, and air conditioners, as well as in farmaceutical and leather industry.

The advent of industry has increased the need for different solvents. While only a few organic solvents were used at the turn of the last century, their number has today increased to several hundreds. Although the primary concern about their usage used to be related to their causing fire and explosion, their toxicological properties have to be considered as well. The most important toxicological properties of organic solvents are their ability to evaporate and to dissolve fats. By dissolving fats, organic solvents can damage haematopoetic tissue, the reproductive system, the nervous sistem, skin and all parenchimatous organs rich in fats (1-8). Having the property to evaporate, they more rapidly contaminate the working environment and, if inhaled, may lead to the poisoning of exposed workers. A danger to health becomes greater and the problem of protection more complex when, in an effort to meet specific production requirenments, various mixtures of organic solvents have to be used.

The aim of this study was to analyse the working environment and occupational hazards in the cartridge, drying and top-coat sections of "Pomoravlje-Niš" paint and laquer factory, and to assess the effects of prolonged exposure to organic solvent mixtures upon the peripheral nervous system in exposed workers.

Subjects and Methods

The analysis of the working conditions, the examination of technological work process and the assessment of physical and chemical factors were done. The concentration of harmful chemical supstances was determined by the methods of titration, spectrophotometry and nephelometry.

The study included 155 workers divided into two groups. The exposed group comprised 100 workers engaged in the production of paint and lacquer in the "Pomoravlje" factory. The control comprised 55 workers with no contact with harmful chemical noxae at their workplaces. The examination of the workers included clinical examination (work, personal and family anamnesis, symptoms and physical signs), neuropsychiatric examination and psychological evaluation. The electromyoneurographic examination was performed in the standard way using two-chanell Dantec cantata 2000 with superficial skin electrodes in order to determine:

- Sensitive conduction velocity of median and peroneal nerve,
- Motor conduction velocity of median and peroneal nerve,
- Terminal latency of median and peroneal nerve.

Response time to light and sound was measured by a psychologist using Denitron PM 95 reactiometer.

The statistical analysis of the obtained data involved the calculation of the arithmetic mean and standard deviation and the tests of statistical significance and differences.

Results

The analysis of the working conditions in the cartridge, drying and top-coat sections of paint and lacquer industry suggests the presence of organic solvents (white spirit and toluene) that is above the maximum allowed value (Table 1).

Table 1. Results of chemical noxae measurement

	Chemical noxae				
	White spirit mg/m^3	Toluen mg/m^3	Butil acetate mg/m^3	Xylen mg/m^3	Ethil acetate mg/m^3
Measured	380	450	290	450	380
Allowed	300	375	290	435	11400

The exposed and control group were of similar structure with respect to age, length of employment, smoking habits and alcohol intake (Table 2 and Table 3).

Table 2. Age and length of employment in the exposed and control group

	Exposed group N=100		Control group N=55		p
	X	SD	X	SD	
Mean age	49.9	7.5	51.2	8.3	n.s.
Length of employment	19.2	6.3	18.9	6.1	n.s.
Lenght of exposure to organic solvents	14.2	5.9	–	–	–

n.s.-non significant difference

Table 3. Alcohol intake and smoking habits in the exposed and control group

	Exposed group N=100		Control group N=55		p
	X	SD	X	SD	
Smokers	63	63.0	35	63.6	n.s.
Regular alcohol consumers	24	24.0	14	25.5	n.s.
Occasional alcohol consumers	76	76.0	41	74.6	n.s.

n.s.- non significant difference

The analysis of the electromyoneurographic findings on the median and peroneal nerve in both the exposed and control group revealed that reduction in motor and sensitive conduction velocity was more statistically significant in the exposed workers compared to controls (Table 4).

Table 4. Electromyoneurographic findings on the median and peroneal nerve in the exposed and control group

Conduction velocity	Exposed group N=100		Control group N=55	
	X	SD	X	SD
Median nerve				
Motor conduction velocity (m/s)	50.1**	4.4	54.2	4.6
Terminal latency(msec)	3.8***	0.4	3.1	0.2
Sensitive conduction velocity (m/s)	52.1***	3.1	58.5	4.1
Peroneal nerve				
Motor conduction velocity (m/s)	49.6*	4.5	51.9	4.7
Terminal latency (msec)	5.2***	0.4	4.1	0.2
Sensitive conduction velocity (m/s)	41.7***	3.9	55.5	5.4

Statistical comparisons between the exposed and control group
*p<0.05, ** p<0.01, ***p<0.001

By analysing the values of motor conduction velocity on the median and peroneal nerve in the exposed group relative to the length of occupational exposure to organic solvents, it was established that longer exposure at worklpaces leads to a proportional and statistically significant reduction in conduction velocity (Table 5).

Table 5. Motor conduction velocity of the median and peroneal nerve in the exposed group relative to the length of occupational exposure

Length of occupational exposure (years)	Number	Median nerve		Peroneal nerve	
		X(m/s)	SD	X(m/s)	SD
0- 9	28	54.5	4.1	53.1	4.7
10-19	22	51.3*	3.9	50.2*	4.4
20-29	27	49.8**	4.2	48.9*	4.2
30-40	23	43.9***	4.3	45.6**	4.1
Total	100	50.1**	4.4	49.6*	4.5

Statistical comparisons relative to the 0-9 year exposure subgroup.
*p<0.05, **p<0.01, ***p<0.001

Sensitive conduction velocity of the median and peroneal nerve in the exposed group reduces concomitant with an increase in the length of employment (Table 6).

Table 6. Sensitive conduction velocity of the median and peroneal nerve in the exposed group relative to the length of employment

Length of occupational exposure (years)	Number	Median nerve		Peroneal nerve	
		X(m/s)	SD	X(m/s)	SD
0- 9	28	56.5	3.1	46.8	3.5
10-19	22	52.3*	3.8	42.3*	3.7
20-29	27	51.8**	2.9	39.1**	4.0
30-40	23	46.9***	3.2	37.9***	4.1
Total	100	52.1**	3.1	41.7**	3.9

Statistical comparisons relative to the 0-9 year-exposed subgroup.
*p<0.05, **p<0.01, ***p<0.001

Terminal latency increased in parallel with the length of employment, marking the most remarkable increase in the subgroups of workers with the length of occupational exposure over 20 years (Table 7).

Table 7. Terminal latency of the median and peroneal nerve in the exposed group relative to the length of employment

Length of occupational exposure (years)	Number	Median nerve		Peroneal nerve	
		X(m/s)	SD	X(m/s)	SD
0- 9	28	3.3	0.2	4.8	0.2
10-19	22	3.6*	0.4	5.1*	0.4
20-29	27	4.1***	0.3	5.2**	0.3
30-40	23	4.2***	0.4	5.8***	0.4
Total	100	3.8**	0.4	5.2**	0.4

Statistical comparisons relative to the 0-9 year-exposed subgroup. *p<0.05, **p<0.01, ***p<0.001

The exposed workers more frequently complained of numbness of the arm and leg, cramps in the shoulder and knee, weakness in the arm and leg than did controls (Table 8).

Table 8. Symptoms in the exposed and control workers

	Exposed group N=100		Control group N=55		p
	Number	%	Number	%	
Numbness of the arm and leg	27	27.0	2	3.6	<0.001
Cramps in the shoulder and knee	17	17.0	2	3.6	<0.05
Weakness in the arm and leg	17	17.0	1	1.8	<0.01
Without symptoms	39	39.0	50	90.9	<0.001

A high degree of correlation was found in the exposed group between the symptoms and the results of electromyoneurographic findings (χ^2 test=10.4) ($p<0.001$) (Table 9).

Table 9. Correlation between symptoms and electromyoneurographic findings in the exposed group

Symptoms	Electromyoneurographic findings			
	Positive		Negative	
	Number	%	Number	%
Present	47	77.1	14	22.9
Absent	3	7.7	36	92.3

Response time to acoustic and visual stimuli was significantly longer in the workers from the exposed group compared to the workers from control ($p < 0.05$) (Table 10).

Table 10. Response time to acoustic and visual stimuli in the exposed and control group

Response time	Exposed group		Control group	
	X (sec)	SD	X (sec)	SD
Acoustic stimulus	0.19*	0.03	0.17	0.02
Visual stimulus	0.25*	0.04	0.22	0.03

Statistical comparisons between the exposed and control group, *p<0.05

Discussion

Exposure to organic solvents is a daily experience for a great many workers. Althought chemically heterogenous, these compounds are often discussed as a group becausse of their similar toxicological effects and a high frequency of exposure to their various combinations (9,10).

Exposure to high concentrations of solvent vapors results in acute narcosis, whilst lower levels may lead to transient intoxication syndrome similar to that seen with ethanol consumption (2,4,6,11).

Organic solvent syndrome is the mildest form of the chronic effect marked by symptoms of irritability, fatigue and reversible difficulty to concentrate. Workers exposed to solvents may exibit numerous syndromes, depending on the intensity and duration of exposure and ranging from a mild decrease in nerve conduction velocity to neuro- and enceohalopathy. Epidemiologic studies have frequently shown a decrease in response time, dexterity, speed and memory and abnormalities in peripheral nervous system function in workers with prolonged solvent exposure (3,4,5,12).

Our study has shown that toxic damage of neuronic transmission is a consequence of sensorimotor toxic peripheral polyneuropathy. These results are in accordance with the results of other autors (2,6,7,12,13).

Two basic forms of damage to peripheral nerves have been identified as responsible for the peripheral neuropaties associated with occupational exposure to organic solvents. Segmental demyelination results from primary destruction of the neuronal myelin sheath, with the relative sparing of the axons.This process begins at the nodes of Ranvier and results in the slowing of nerve conduction. Axonal degeneration is associated with metabolic derangement of the entire neuron and is manifest in degeneration of the distal portion of the nerve fiber. Myelin sheath degeneration may occur secondarily. This form of axonal degeneration was originally described as "dying back" neuropathy. In many instances, axonal degeneration and segmental demyelination may coexist, presumably due to the econdary effects derived from damage to each system (14). The clinical manifestations of neuropathy in exposed individuals may represent a combination of both pathologic processes (14,15).

Electrophysiologic tests that assess peripheral nerves, including electromyogram and nerve conduction measurements, are important tools in assessing the extent and severity of neurologic disorders in workers exposed to industrial organic solvents.These techniques are often useful in the evaluation of individual patients. These studies have given a particular contribution to early detection of subclinic lesions of the peripheral nervous system, which is of great value given that the nervous system has a limited capacity for regeneration.

Our study has revealed a statistically significant reduction in sensitive and motor conduction velocity of the median and peroneal nerve. Other autors have found

a statistically significant reduction in conduction velocity of motor and sensitive nerves in relation to the control group (2,3,5,13). A statistically significant difference has been found between the groups that are moderately and highly exposed to mixtures of organic solvents with respect to degree of conduction velocity reduction (1,6).

The initial manifestations of these disorders include intermittent numbness and tingling in the hand and foot and motor weakness in the foot or hand. Extensor muscle groups usually manifest weakness before flexors do (15).

In our study, the most frequent symptoms that appear in the exposed workers include numbness, cramps and weakness in the arm and leg. These symptoms occur in 60% workers exposed to organic solvents. Other authors record even a higher percentage of symptoms (16). A statistically significant difference in the occurrence of symptoms typical of peripheral neuropathy is noticed in painters exposed to mixtures of organic solvents (17,18,19). These symptoms may be early indicators of the peripheral nervous system's chronic exposure to organic solvents. Development of these symptoms is usually insidious. A very slow development of numbness and tingling of the fingers and toes occurs within several weeks and may be followed by motor weakness (20).

Prevention of occupationally induced neurological disorders can be accomplished through workplace medical and environmental control programs. The goal of environmental control is to reduce concentrations of organic solvents in the working environment by various measures. Medical strategies designed to reduce neurological morbidity include pre-employment or pre-placement evaluation and periodic medical monitoring. The goal of pre-employment or pre-placement evaluation pertaining to neurological disorders is to avoid the placement of individuals with a preexisting disease at jobs with exposure that might exacerbate these conditions.

Conclusion

The monitoring of the working environment in paint and lacquer industry has revealed the presence of toluene and white spirit above the allowed values. By the analysis of the symptoms and results of clinical and electromyoneurographic examination, the presence of neurotoxic effects of these agents in the working environment has been discovered.

The results suggest an urgent need for preventive measures that would protect the health of exposed workers.

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UTICAJ ORGANSKIH RASTVARAČA NA PERIFERNI NERVNI SISTEM EKSPONOVANIH RADNIKA

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Kratak sadržaj: *Analizom uslova radne sredine u pogonima šaržiranja, odležavanja i premaza industrije boja i lakova utvrđeno je prisustvo vajtšpirita i toluena iznad dozvoljenih vrednosti.*
Eksponovanu grupu je činilo 100 radnika profesionalno eksponovanih ovim noksama, dok je u kontrolnoj grupi bilo 55 radnika koji nikada u svom radnom veku nisu bili izloženi hemijskim noksama.
Radnici eksponovanih grupa su se češće žalili na trnjenje ruku i nogu grčeve u ramenima i kolenima i slabost u nogama i rukama u odnosu na radnike kontrolne grupe. Elektroneurografski nalaz na n. medianusu i n. peroneusu pokazao je znatno manje brzine motorne i senzitivne provodljivosti u eksponovanoj u odnosu na kontrolnu grupu. Registrovano je smanjenje ovih brzina sa dužinom ekspozicije noksama na radnom mestu. Terminalna latenca na n. medianusu i n.peroneusu je statistički značajno veća u eksponovanoj u odnosu na kontrolnu grupu, pri čemu njena vrednost u eksponovanoj grupi raste sa dužinom eksponovanog radnog staža. Radnici eksponovane grupe su imali statistički značajno duže vreme reakcije na akustičku i vizuelnu draž u odnosu na radnike kontrolne grupe. Rezultati ovog rada ukazuju na neurotoksične efekte noksi registrovanih u ovoj industriji.

Ključne reči: *Organski rastvarači, n. peroneus, n. medianus, elektroneurografsko ispitivanje*