Original Article

A Study on Neurobehavioral Performance of Workers Occupationally Exposed to Solvent in Synthetic Resin Manufacturing

Asim Saha, S. R. Tripathi[1]

Department of Epidemiology, Regional Occupational Health Centre (Eastern), Salt Lake, Kolkata, West Bengal, [1]Department of Psychology, National Institute of Occupational Health, Ahmedabad, Gujarat, India

ABSTRACT

Background: One major effect of occupational solvent exposure is central nervous system (CNS) impairment, ranging from depression to encephalopathy with cognitive, behavioral changes. Exposures in industries being varied, classification of health outcomes for different exposures is important. **Objectives:** This study assessed neurobehavioral performance of synthetic resin manufacturing workers exposed to organic solvent, mainly formalin. **Materials and Methods:** This cross-sectional study selected subjects by random selection from all such workers of an Indian city. Questionnaire survey and assessment by a neurobehavioral test battery (NBT) was undertaken. **Results:** Comparison between actual and allied workers observed significant difference in tweezer dexterity, card sorting and backward memory scores. Significant effect of exposure was observed on tweezer dexterity, card sorting, and hand dynamometer scores. **Conclusion:** Changes of neurobehavioral performance might occur following solvent exposure and these changes might have a relationship with the quantum of exposure. Periodic examination of workers with NBT is needed for detection of early neurotoxic effects.

Key words: Neurobehavioral performance, occupational solvent exposure, synthetic resin

INTRODUCTION

Organic solvents have been reported to adversely affect human health, especially in relation to occupationally exposed group. Classical findings include various symptoms related to central nervous system, local effects (e. g., eyes, nose, and throat) and dizziness, floating sensations, etc., Dizziness and floating sensations were identified as typical symptoms with significant dose–response relationship. Several symptoms persisted off work, most of which were apparently related but not necessarily limited to central nervous system (CNS) effects. Some symptoms followed a statistically significant dose–response relationship also.[1] Organic solvents have been reported to adversely affect human health in many ways. Animal models have demonstrated that solvents may induce auditory damage, especially to the outer hair cells. Research on workers exposed to organic solvents has suggested that these chemicals may also induce auditory damage through effects on the central pathways.[2,3] Although no significant alteration of hematological parameters after such exposures was found in some studies,[4,5] some researchers observed changes in the peripheral blood of exposed workers.[6,7] An investigation to study the effect of paint thinner inhalation on testosterone synthesis and secretion (using male rats) observed reversible decrease of serum testosterone levels when determined by chemiluminiscence

Access this article online	
Quick Response Code:	Website: www.toxicologyinternational.com
	DOI: 10.4103/0971-6580.155346

Address for correspondence: Dr. Asim Saha, Scientist D, Regional Occupational Health Centre (Eastern), Salt Lake, Kolkata-700 091, West Bengal, India. E-mail: asimsaha2311@yahoo.co.in

enzyme immunoassay.[8] Exposure to solvent is also reported to affect total protein, total bilirubin, transaminase, and gamma-glutamyl transpeptidase (GT) values.[9] One of the major effects of exposure is central nervous system (CNS) impairment, ranging from a reversible CNS depression to chronic solvent-induced encephalopathy (CSE) due to long-term exposure. CSE comprises cognitive and behavioral changes, such as short-term memory loss, attentional impairment, fatigue, and mood and personality changes.[10,11] Exposure to mixed organic solvents is found to alter blood pressure of exposed nonsmoking workers.[12]

Solvent exposure is ubiquitous in the general population also. A study measured the organic solvents such as benzene, xylene, styrene, toluene, and other volatile organic chemicals in the blood and detectable concentrations were found in most of the blood samples.[1] Organic solvents are also commonly used in the workplace. Around 9.8 million US workers were occupationally exposed to solvents as estimated by National Institute for Occupational Safety and Health (NIOSH). Organic solvents such as benzene, toluene, and related compounds have also been identified as the potential reproductive toxins. Although the level of exposure in most modern industries is far below the limit recommended by the Occupational Safety and Health Administration; however, studies have begun to suggest that even low-level occupational exposure may be associated to a broad spectrum of adverse health outcomes.

Exposures in different industries are varied and composite in nature. Hence, health effects observed is difficult to be related to any specific exposure. As far as solvents are concerned, the family consists of an array of chemicals. Classification of health outcomes according to specific nature of exposure is of utmost importance in order to plan prevention as well as intervention.

This study was initiated to assess the neurobehavioral performance of workers engaged in synthetic resin manufacturing industry where principal exposure is from organic solvent, mainly formalin.

MATERIALS AND METHODS

This study was undertaken among the workers exposed to organic solvent engaged in synthetic resin manufacturing processes. These workers were selected using the principles of random selection from a list of all workers of such industries of a city of India. These workers were from synthetic resin manufacturing industry where principal exposure is from organic solvent, mainly formalin. The manufacturing process of these industries is based on the principles of chemical mixing. The heart of the process is a chemical mixer. Different raw materials, mainly chemicals, are added to the mixer through different inlets at calculated intervals with regulated reaction time, temperature, and pressure. The product is extracted through the outflow tract.

This cross-sectional, epidemiological study involved workers from three industries of similar manufacturing process. Initially, the aim of the occupational health study was explained to the workers, informed consent was obtained after which they were enrolled for this study. Every individual subject was interviewed with a predesigned questionnaire to collect information in relation to personal, occupational, and morbidity details of the workers. The participants of this study were subjected to a neurobehavioral test battery (NTB) comprising of following tests.

Finger dexterity

Removing rivette from a hole in the upper part of the board with the preferred hand, and at the same time removing one washer from a vertical stack on a peg with the other hand; assembling the washer on the rivette; and inserting the assembly into the corresponding hole in the lower part of the board. Time duration was 180 s.

Score: Number of assembly inserted.

Tweezer dexterity

The apparatus comprised of a steel board with 100 holes (1cm deep and 1.5 mm in diameter arranged in 10 rows). The subject is supposed to put cylindrical metallic pins (2.5 mm long and 1.5 mm in diameter) with the help of a tweezer into the holes as fast as he can do in 180 s.

Score: Number of successful events.

Card sorting

This test assesses abstract reasoning ability and the ability to shift cognitive strategies in response to changing environmental contingencies. Result is expressed in the form of time taken to accomplish the job.

Hand steadiness test

This test is designed to measure the finger tremor where subject has to insert a stylus into a hole from 6 cm diameter to 0.5 cm diameter without touching the wall of hole. Result is expressed as the number of mistakes committed during the job.

Hand dynamometer

This measures the hand strength in kilograms.

Memory

Test for assessment of memory is conducted by examining the power to recall in both forward and backward direction and is expressed as respective scores.

NBT was applied to evaluate effects of solvent exposure on tweezer dexterity, finger dexterity, hand steadiness, card sorting (design and face value), forward and backward memory, and hand dynamometer. While analyzing the data, score were considered to see the effect of solvent on the neurobehavioral test performance. One-way analysis of variance was carried out to compare the different NBT parameters. The effect of age and exposure was assessed separately. Comparison between actual and allied workers was also taken up.

As far as statistical analysis of data is concerned, initially a descriptive analysis was performed to obtain basic details of the study parameters. Afterwards, analysis of variance was used to ascertain age and job experience wise difference in relation to different neurobehavioral test parameters.

RESULTS

Analysis of the collected data showed that mean age of the workers was 34.3 ± 10.9 years, mean job duration was 11.4 ± 10.0 years, majority (43%) was up to 30 years of age, and 31% subjects had work experience of more than 15 years. About 38% were allied workers with partial exposure and 61.7% were actual workers involved in main activity related to exposure. Approximately 19% workers were either smokers or ex-smokers. About 97% of workers were educated up to secondary level or higher [Table 1].

While comparing allied and actual workers, it was observed that statistically significant difference was observed between the two groups in respect to tweezer dexterity, card sorting (face and design both), backward memory, and hand dynamometer [Table 2].

When the NBT results were analyzed with reference to age group, it was found that the score was decreasing with age in case of hand dynamometer experiment. This difference was statistically significant also. Decreased level of performance was also observed with increasing age in card sorting and memory experiments (though statistically nonsignificant) [Table 3].

On exposure, from the group-wise analysis of NBT results, it was evident that tweezer dexterity score was significantly affected by increasing duration of exposure. Statistically significant effect of increasing duration of exposure was also observed on analysis of card sorting (face) and hand dynamometer test results [Table 4].

Table 1: General characteristics of the study subjects (*N*=149)

Variables	Values
Age group (year) (%)	
Upto 30 years	64 (42.7)
31-45 years	61 (40.7)
Above 45 years	24 (16.7)
Mean age	34.3±10.9 years
Worker group (%)	
Allied worker	57 (38.2)
Actual worker	92 (61.7)
Experience group (year) (%)	
Upto 5	62 (41.6)
6-15	41 (27.5)
Above 15	46 (30.9)
Mean experience	11.4±10.0 years
Smoking status (%)	
Nonsmoker	121 (81.2)
Smoker	16 (10.7)
Ex-smoker	12 (8.1)
Educational status (%)	
Illiterate	4 (2.7)
Upto secondary level	86 (57.7)
Upto college level	59 (39.6)
Mean family size	5.15±1.8
Mean height	165.3±7.2 cm
Mean weight	58.4±10.5 kg

Table 2: Comparison of neurobehavioral test parameters between actual and allied workers

Name of tests	Age group	Mean	SE	*F*	*P*
Tweezer dexterity (total score)	Allied workers	38.39	1.21	8.46	0.003
	Actual workers	33.84	0.96		
Finger dexterity (total score)	Allied workers	30.61	0.42	2.4	0.10
	Actual workers	29.15	0.66		
Hand steadiness	Allied workers	5.23	0.12	0.83	0.36
	Actual workers	5.42	0.18		
Card sorting (design)	Allied workers	33.26	1.01	5.58	0.01
	Actual workers	36.92	1.10		
Card sorting (face)	Allied workers	130.21	4.11	6.08	0.01
	Actual workers	144.62	3.32		
Hand dynamometer	Allied workers	41.30	1.12	11.17	0.001
	Actual workers	36.20	0.98		
Forward memory	Allied workers	5.3	0.9	0.16	0.68
	Actual workers	4.7	1.0		
Backward memory	Allied workers	3.8	0.3	4.07	0.04
	Actual workers	3.1	0.2		

SE = Standard error

DISCUSSION

In the backdrop of varied mixed exposure to different solvents in industries, keeping in view the fact that prevention is the only way to combat morbidity under such circumstances, it is of utmost importance not only

Table 3: Age group-wise comparison of neurobehavioral test parameters

Name of tests	Age group	Mean	SE	*F*	*P*
Tweezer dexterity (total score)	Upto 30 years	38.02	0.83	0.88	0.41
	31-45 years	39.05	1.33		
	Above 45 years	36.41	1.80		
Finger dexterity (total score)	Upto 30 years	30.42	0.40	2.019	0.136
	31-45 years	30.15	0.56		
	Above 45 years	28.32	1.41		
Hand steadiness	Upto 30 years	5.35	0.10	0.658	0.519
	31-45 years	5.19	0.12		
	Above 45 years	5.38	0.17		
Card sorting (design)	Upto 30 years	32.52	1.13	2.540	0.082
	31-45 years	34.48	1.48		
	Above 45 years	38.20	2.47		
Card sorting (face)	Upto 30 years	129.18	3.34	1.94	0.14
	31-45 years	140.29	4.93		
	Above 45 years	135.85	4.59		
Hand dynamometer	Upto 30 years	41.41	0.76	6.750	0.002
	31-45 years	40.25	0.93		
	Above 45 years	35.60	1.36		
Forward memory	Upto 30 years	5.1	1.0	0.01	0.98
	31-45 years	4.9	0.6		
	Above 45 years	4.9	0.5		
Backward memory	Upto 30 years	3.6	0.8	0.02	0.97
	31-45 years	3.5	0.7		
	Above 45 years	3.3	0.6		

SE = Standard error

Table 4: Exposure group-wise comparison of neurobehavioral test parameters

Name of tests	Exposure group	Mean	SE	*F*	*P*
Tweezer dexterity (total score)	Upto 5 years	39.48	0.82	6.35	0.002
	6-15 years	37.82	1.00		
	Above 15 years	33.56	1.80		
Finger dexterity (total score)	Upto 5 years	30.02	0.48	0.923	0.400
	6-15 years	30.59	0.70		
	Above 15 years	29.26	0.81		
Hand steadiness	Upto 5 years	5.24	0.10	0.174	0.840
	6-15 years	5.34	0.15		
	Above 15 years	5.32	0.13		
Card sorting (design)	Upto 5 years	33.60	1.23	0.995	0.372
	6-15 years	33.39	1.53		
	Above 15 years	36.22	1.89		
Card sorting (face)	Upto 5 years	128.86	3.38	6.81	0.001
	6-15 years	132.69	3.54		
	Above 15 years	151.68	6.76		
Hand dynamometer	Upto 5 years	41.34	0.78	6.047	0.003
	6-15 years	41.22	1.17		
	Above 15 years	37.11	1.01		
Forward memory	Upto 30 years	5.2	0.5	0.27	0.75
	31-45 years	5.0	0.4		
	Above 45 years	4.7	0.5		
Backward memory	Upto 30 years	3.7	0.6	0.12	0.88
	31-45 years	3.5	0.6		
	Above 45 years	3.3	0.5		

SE = Standard error

to classify health outcomes according to specific exposure but also to identify preclinical effects of low-level chronic exposure on the cognitive performance.

A study of psychological effects of occupational exposure to organic solvent mixtures on printers proved not only that chronic exposure to organic solvent mixtures could induce a psychological effect but also that the psychological/psychometrical tests performed in this study were capable of predicting neurotoxicity.[13] Another study on car painters with long-term exposure to solvents showed psychological deviations such as deficits in concentration, memory, and reaction time compared to unexposed subjects.[14] A research to examine the effects of inhalation of toluene on neuropsychological performance of humans showed that performance of complex tests and response time to simple brief tests can be disrupted by toluene inhalation at 100 ppm. Differences in performance between air and toluene conditions were greatest after exercise, indicating that physical activity may enhance the response to volatile organic solvents.[15] A study of workshop painters of a public transport network in Indian context observed significant degradation in performance on tests of critical flicker fusion (alternate), letter cancellation, Muller-Lyer illusion, and card sorting following solvent exposure.[16] Neuropsychiatric function was assessed in a study of housepainters with previous long-term heavy exposure to organic solvents. Neuropsychiatric symptoms compatible with chronic toxic encephalopathy were found to be more common among the painters than among the carpenters, and these symptoms became increasingly prevalent with increasing cumulative solvent exposure.[17] Psychological evaluation of the effects of chronic occupational exposure of paint shop workers to the mixture of organic solvents was undertaken in another study. In the exposed workers, a longer simple reaction time was observed, as well as reduced manual skills and impaired precision of the hand movements.[18] A study on psychomotor effects of mixed organic solvent exposure revealed that the exposed workers had a lower performance compared to nonexposed workers in all psychomotor tests.[19] However, there are also studies that could not prove evidence for psychological performance effects due to long-term relatively lower level solvent exposure.[20]

In this present study, significant difference of some of the test results of the NBT applied was observed when compared between actual exposed workers and allied workers with lesser exposure. Similarly, changes in some of the test result values were also significant with increasing duration of exposure. Like some other previous studies, our study also concluded that changes of neurobehavioral performance might take place following chronic occupational exposure to solvent and amount of the change occurred might be in a relationship with the quantum of exposure. Finally, this study suggested that regular periodic medical examination of workers should be in place with inclusion of psychopathologic methods for detection of early neurotoxic effects of organic solvent exposures.

ACKNOWLEDGEMENT

We acknowledge the help of the subjects who participated in this study and also the support of the industries where the study was conducted. We are thankful to the Director, National Institute of Occupational Health and Indian Council of Medical Research authorities for their support.

REFERENCES

1. Ukai H, Watanabe T, Nakatsuka H, Satoh T, Liu SJ, Qiao X, *et al*. Dose-dependent increase in subjective symptoms among toluene-exposed workers. Environ Res 1993;60:274-89.
2. Fuente A, McPherson B. Organic solvents and hearing loss: The challenge for audiology. Int J Audiol 2006;45:367-81.
3. Fuente A, McPherson B, Cardemil F. Xylene-induced auditory dysfunction in humans. Ear Hear 2013;34:651-60.
4. Ukai H, Takada S, Inui S, Imai Y, Kawai T, Shimbo S, *et al*. Occupational exposure to solvent mixtures: Effects on health and metabolism. Occup Environ Med 1994;51:523-9.
5. Chen Z, Liu S, Cai S, Yao Y, Yin H, Ukai H, *et al*. Exposure of workers to a mixture of toluene and xylenes. II. Effects. Occup Environ Med 1994;51:47-9.
6. Hristeva-Mirtcheva V. Changes in the peripheral blood of workers with occupational exposure to aromatic hydrocarbons. Int Arch Occup Environ Health 1998;71:S81-3.
7. Kamal A, Malik RN. Hematological evidence of occupational exposure to chemicals and other factors among auto-repair workers in Rawalpindi, Pakistan. Osong Public Health Res Perspect 2012;3:229-38.
8. Yilmaz B, Canpolat S, Sandal S, Akpolat N, Kutlu S, Ilhan N, *et al*. Paint thinner exposure inhibits testosterone synthesis and secretion in a reversible manner in the rat. Reprod Toxicol 2006;22:791-6.
9. Caciari T, Casale T, Pimpinella B, Montuori L, Trovè L, Tomei G, *et al*. Exposure to solvents in health care workers: Assessment of the hepatic effects. Ann Ig 2013;25:125-36.
10. Mikkelsen S. Epidemiological update on solvent neurotoxicity. Environ Res 1997;73:101-12.
11. White RF, Proctor SP. Solvents and neurotoxicity. Lancet 1997;349:1239-43.
12. Mohammadi S, Golabadi M, Labbafinejad Y, Pishgahhadian F, Attarchi M. Effects of exposure to mixed organic solvents on blood pressure in non-smoking women working in a pharmaceutical company. Arh Hig Rada Toksikol 2012;63:161-9.
13. Böckelmann I, Pfister EA, Peters B, Duchstein S. Psychological effects of occupational exposure to organic solvent mixtures on printers. Disabil Rehabil 2004;26:798-807.
14. Böckelmann I, Darius S, McGauran N, Robra BP, Peter B, Pfister EA. The psychological effects of exposure to mixed organic solvents on car painters. Disabil Rehabil 2002;24:455-61.
15. Rahill AA, Weiss B, Morrow PE, Frampton MW, Cox C, Gibb R, *et al*. Human performance during exposure to toluene. Aviat Space Environ Med 1996;67:640-7.
16. Tripathi SR, Bhattacharya SK, Kashyap SK. Neurobehavioural changes in workshop painters of a public transport network. J Hum Ergol (Tokyo) 1995;24:153-60.
17. Lundberg I, Michélsen H, Nise G, Hogstedt C, Högberg M, Alfredsson L, *et al*. Neuropsychiatric function of housepainters with previous long-term heavy exposure to organic solvents. Scand J Work Environ Health 1995;21:1-44.
18. Waszkowska M, Bazylewicz-Walczak B. Psychological evaluation of the effects of chronic occupational exposure of paint shop workers to the mixture of organic solvents. Med Pr 1992;43:35-9.
19. Aminian O, Hashemi S, Sadeghniiat-Haghighi K, Shariatzadeh A, Naseri Esfahani AH. Psychomotor effects of mixed organic solvents on rubber workers. Int J Occup Environ Med 2014;5:78-83.
20. Seeber A, Schäper M, Zupanic M, Blaszkewicz M, Demes P, Kiesswetter E, *et al*. Toluene exposure below 50 ppm and cognitive function: A follow-up study with four repeated measurements in rotogravure printing plants. Int Arch Occup Environ Health 2004;77:1-9.

How to cite this article: Saha A, Tripathi SR. A Study on Neurobehavioral Performance of Workers Occupationally Exposed to Solvent in Synthetic Resin Manufacturing. Toxicol Int 2014;21:264-8.

Source of Support: Nil. **Conflict of Interest:** None declared.