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### A comparison of Health Hazard Effects by Solvent-based and Water-based Painting materials

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The purpose of this study is to substitute water-based painting materials for the current solvent-based ones used in motor-repairing process to minimize the exposure of organic solvents to the painters.

This study assessed the exposure of organic solvents to the painters using water-based and solvent-based painting materials and compared compositions, painting processes and the health hazards of the application of these alternative painting materials.

The results of this study are as follows.

1. solvent-based painting materials used in motor-repairing process consist of various organic solvents, which consist primarily of toluene, xylene, ethyl benzene, ethyl methyl benzene, trimethyl benzene, ethyl acetate, butyl acetate, methyl isobutyl ketone, 2-ethoxy ethanol, 2-ethoxy ethyl acetate and toluene-2,4-diisocyanate and the others. These organic solvents are known as health-hazardous substances. But water-based painting materials are high-solid, low-solvent

ones and consist of such two organic solvents as 2-butoxy ethanol and 2-heptanone and the others.

2. The painters using solvent-based painting materials in motor-repairing process are exposed to various organic solvents which consist of toluene, xylene, ethyl acetate, butyl acetate, methyl isobutyl ketone, trimethyl benzene, 2-ethoxy ethanol, and 2-ethoxy ethyl acetate. But the painters using solvent-based ones are only exposed to 2-butoxy ethanol and 2-heptanone.

3. By using water-based painting materials in stead of solvent-based painting materials containing health-hazardous organic solvents, the exposure of such organic solvents in the painter's breathing zone can be largely prevented.

4. This study recommends water-based painting materials as substitutes for the current solvent-based ones used in motor-repairing process to minimize the exposure of organic solvents to the painters.

*Key Words* : Water-based, Solvent-based, Organic solvent

#### I.

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(paint)

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(ACGIH, 1999).

( , ),  
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가 (가 , , ) 가  
4가

I(Surfacer)  
(Colorbase)

가  
(NIOSH, 1984; Burgess, 1995;  
, 1996).

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2)

(thinner)

(sandpaper) #80

( )  
(NIOSH, 1984; Burgess, 1995).

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#80 1 , #180 2

( #180, #320)

( ( ), 1999).

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( #400, #320)

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( , 1997; ,  
1998; , 1999;  
, 1999).

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#320

(ACGIH, 1997).

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 2.  
 ( , , )  
 Gas Chromatography (Hewlett Packard, 5890 Series )/Mass Selective Detector(Hewlett Packard, 5971 Series) (GC/MSD)  
 1  
 ( , , )  
 CS2 Syringe filter  
 (Pore size 0.45 µm, Millex-SR 25MM Millipore Co.)  
 0.2 1µℓ GC  
 Gas Chromatography  
 MSDS  
 가  
 Mass Detector total  
 abundance (%)  
 3.  
 1)  
 (National Institute for Occupational Safety and Health, NIOSH)  
 (Gilian, U.S.A)  
 0.01 0.2 Lpm  
 20/40mesh  
 (100mg/50mg)  
 3) : (dry painting)  
 4) : (wet painting)

Table 1. Systems and operating conditions for qualitative analysis of organic solvents by GC/MSD

Variable	Condition
<b>Systems</b>	
Gas Chromatography	Hewlett Packard 5890 Series /MSD, HP 5971 Series
Detector	MSD(Mass Selective Detector)
Capillary Column	HP-1(50m × 0.2mm × 0.50µm)
<b>Operating Conditions</b>	
Injection Mode	Split(100:1)
Injector Temperature	300
Detector Temperature	320
Oven Temperature Programming	70 to 200
Carrier gas	He 0.712Mℓ/min
Electron energy	70eV
Database for searching mass spectrum	Wiley 138 Library

Plus) 2  
 (15 30 )  
 0.01 0.2  
 Lpm ethoxy ethanol butoxy ethanol (octane)  
 0.05 Lpm) CS2 1Mℓ  
 TH-KIT(dual holder) ethoxy ethanol butoxy ethanol  
 5% (NIOSH Method No. 1403, 1994 : , 1997).  
 (IKAR -WERKE, Germany)  
 30  
 가  
 3 5가  
 2)  
 (FID)가 Gas Chromatography(Hewlett Packard HP-6890)

Table 2. Systems and operating conditions for quantitative analysis of organic solvents by GC

Variable	Condition
<b>Systems</b>	
Gas Chromatography	Hewlett Packard 6890 Plus
Detector	FID(Flame Ionization Detector)
Capillary Column	HP-INNOWax(30m × 0.32mm × 0.50µm)
<b>Operating Conditions</b>	
Injection Mode	Split(20:1)
Injector Temperature	250
Detector Temperature	300
Oven Temperature Programming	40 to 200

Table 3. The result of qualitative analysis of organic solvents by GC/MSD

1.	Composition(%)	Solvent-based			water-based	
		Color base	Surfacer	Hardener	Color base	Surfacer
GC/MSD	2-ethoxy ethanol	0.25				
	2-butoxy ethanol				98.54	43.15
	2-Heptanone					45.00
	2-ethoxy ethyl acetate	11.18				
	toluene	13.94	57.32	43.92		
	MIBK	0.54				
	n-butyl acetate			22.54		
	ethyl benzene	7.14	3.01	2.35		
	ethyl acetate	24.99	19.38	5.06		
	xylene	36.62	18.63	16.07		
	trimethyl benzene	3.06				
	ethyl methyl benzene	2.07				
	2,4 TDI					
			0.21	0.67	10.07	1.46

2-butoxy ethanol, 2-heptanone

Table 4. Composition of solvent-based painting materials by MSDS1

Composition	Solvent-based(%)		
	Color base	Surfacer	Hardener
2-ethoxy ethyl acetate	10-20		10-20
toluene	5-15	10-20	21-30
butyl acetate	10-20	1-10	
ethyl acetate		1-10	
xylene	10-20		
Diisocyanate polymer			41-50
Titanium dioxide		5-15	
Talc		10-20	
Acryl resin		21-30	
S1(confidential)	1-10	1-10	

(Bernstein, 1996; Musk et al., 1988).

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(MSDS)

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GC-MSD

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2-ethoxy

ethanol, 2-ethoxy ethyl acetate, toluene, methyl isobutyl ketone, butyl acetate, ethyl benzene, m-xylene, o-xylene, p-xylene, 123-trimethyl benzene, 124-trimethyl benzene, 135-trimethyl benzene

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(Threshold Limit Value-Time Weighted Average, TLV-TWA)

lot

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(LOD, Limit Of Detection)

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GC/MSD

2.

toluene

가

butyl

acetate가

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( 1 13.50 ppm),

5.33 ppm, 2.0 toluene, m-xylene

GC/MSD

(Pilot test)

2-butoxy ethanol

Table 5. Comparison of airborne concentrations of organic solvent in painting with colorbase

Composition	Solvent-based paint (N*=8)				Water-based paint (N*=6)			
	GM †(ppm)	GSD ‡	Range(ppm)		GM †(ppm)	GSD ‡	Range(ppm)	
2-ethoxy ethanol	1.00	1.18	0.79	1.29	-	-	-	-
2-butoxy ethanol	-	-	-	-	3.33	1.12	2.74	3.79
2-ethoxy ethyl acetate	0.74	2.22	0.21	2.10	-	-	-	-
toluene	2.20	1.71	1.16	5.42	0.06	1.54	0.03	0.10
methyl isobutyl ketone	0.17	1.95	0.09	0.54	-	-	-	-
butyl acetate	5.33	1.96	2.01	13.50	-	-	-	-
ethyl benzene	0.72	1.90	0.31	1.97	-	-	-	-
m-xylene	2.23	1.84	0.97	5.69	-	-	-	-
o-xylene	0.86	1.98	0.34	2.44	-	-	-	-
p-xylene	0.70	2.78	0.10	2.53	-	-	-	-
123-trimethyl benzene	0.01	-	0.01		-	-	-	-
124-trimethyl benzene	0.09	2.58	0.02	0.32	-	-	-	-
135-trimethyl benzene	0.05	1.50	0.04	0.07	-	-	-	-

\* : Number of samples, † : Geometric Mean, ‡ : Geometric Standard Deviation

3.33 ppm, 2.74 3.79 ppm (side door 2 , fender 4 )  
 2-butoxy ethanol 가  
 toluene ( )  
 , ( , (thinner)  
 ), , ( 17  
 , ), , ( , 1) (Colorbase)  
 가  
 , 27 29 가  
 , 53 55% 6

Table 6. Comparison of airborne concentrations of organic solvents in painting with colorbase

Composition	Solvent-based paint (N*=8)				Water-based paint (N*=8)			
	GM †(ppm)	GSD ‡	Range(ppm)		GM †(ppm)	GSD ‡	Range(ppm)	
2-ethoxy ethanol	2.26	1.20	1.66	2.65	-	-	-	-
2-butoxy ethanol	-	-	-	-	4.72	2.20	1.10	11.57
2-ethoxy ethyl acetate	3.03	1.76	1.17	4.37	-	-	-	-
toluene	14.88	1.50	7.48	19.12	-	-	-	-
methyl isobutyl ketone	1.84	1.58	0.85	2.50	-	-	-	-
butyl acetate	24.54	1.57	11.56	32.59	-	-	-	-
ethyl benzene	7.56	1.58	3.56	10.10	-	-	-	-
m-xylene	17.86	1.56	8.50	23.73	-	-	-	-
o-xylene	6.26	1.60	2.88	8.43	-	-	-	-
p-xylene	8.05	1.58	3.77	10.77	-	-	-	-
123-trimethyl benzene	0.01	-	0.01		-	-	-	-
124-trimethyl benzene	0.23	2.25	0.06	0.39	-	-	-	-
135-trimethyl benzene	0.10	1.12	0.00	0.12	-	-	-	-

\* : Number of samples, † : Geometric Mean, ‡ : Geometric Standard Deviation

				toluene(150 ppm), xylene(150 ppm), ppm	
				methyl isobutyl ketone(75 ppm), butyl (TLV-STEL)	
	가			acetate(200 ppm), ethyl benzene(125 ppm)	
2-ethoxy ethanol, 2-ethoxy ethyl acetate,				( , 1998 ; ACGIH, 1999).	
toluene, methyl isobutyl ketone, butyl			2) (Surfacer)		2-ethoxy ethanol
acetate, ethyl benzene, xylene(m, o, p),			6		
trimethyl benzene(123, 124, 135) ,					2-heptanone
2-butoxy ethanol					
		butyl			
acetate( 24.54 ppm, 11.56		가		7	
32.59 ppm)가		가			
, m-xylene( 17.86					
ppm, 8.50 23.73 ppm), toluene( 가					
14.88 ppm, 7.48 19.12 ppm)					
2-butoxy ethanol					
4.72 ppm, 1.10 11.57 ppm					가
		가			
		가			
( 5)					(1997)
가 , 가					
				toluene(	
				27.76 ppm, 15.79 35.36 ppm)	TDI가
(15 )				가	
				, butyl acetate( 21.82 ppm,	
(TLV-STEL, short-term expo-				11.71 28.83ppm)가	
sure limit)				10.96 ppm, 5.96 14.34 ppm)	
				2-butoxy ethanol	
				6.91 ppm, 5.73 7.92	

Table 7. Comparison of airborne concentrations of organic solvents in painting with surfacer

Composition	Solvent-based paint (N*=8)				Water-based paint (N*=7)			
	GM †(ppm)	GSD ‡	Range(ppm)		GM †(ppm)	GSD ‡	Range(ppm)	
2-butoxy ethanol	-	-	-		6.91	1.13	5.73	7.92
2-ethoxy ethyl acetate	0.14	1.70	0.06	0.21	-	-	-	
toluene	27.76	1.40	15.79	35.36	0.01	2.03	0.00	0.02
methyl isobutyl ketone	1.66	1.43	0.91	2.19	-	-	-	
butyl acetate	21.82	1.45	11.71	28.83	-	-	-	
ethyl acetate	0.27	2.76	0.00	0.50	-	-	-	
ethyl benzene	4.24	1.47	2.25	5.58	-	-	-	
2-heptanone	-	-	-		1.89	1.47	1.00	2.45
m-xylene	10.96	1.45	5.96	14.34	-	-	-	
o-xylene	3.60	1.48	1.90	4.80	-	-	-	
p-xylene	4.95	1.46	2.64	6.53	-	-	-	

\* : Number of samples, † : Geometric Mean, ‡ : Geometric Standard Deviation

가 20% ( )  
 , 1999).  
 9  
 (Thinner) ( )  
 , 1999)  
 ( TDI)가 ( ), 1999).

(Wieslander et al., 1994; 3)  
 Burgess, 1995).

가 가  
 2-ethoxy ethanol 2-ethoxy ethyl acetate , 가  
 2-butoxy ethanol ) 가  
 2-butoxy ethanol( 25 ppm) 가  
 2-ethoxy ethanol 2-ethoxy ethyl acetate 가  
 ( 5 ppm) 가  
 가 가 4)

( , 1998). 2-ethoxy ethanol, 2-ethoxy ethyl acetate, 2-butoxy ethanol 가  
 가 가 (Volatile Organic Compounds, VOC)

가  
 1) (Richard et al., 1998; Wieslander et al., 1997; ( ) , 1999) 가  
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 가

가 ( ( ), 1999).

2) 가 가

Table 8. The percentage of production by the type of painting materials in the world

	The type of painting materials(%)		
	Water-based	Solvent-based	The others
North America	43	51	6
Latin America	25	71	4
West Europe	34	52	14
Japan	17	80	2
China	15	80.5	4.5

Table 9. The present conditions of the use of water-based painting materials by Motors company in Germany

Motors company	Factory	Basecoat	Solid color	Surfacer	Top coat clear
BMW	REGESBURG	WB	SB	SB	2K
	MUENCHEN	WB	SB	SB	SB
	DINGOLFING	SB	SB	SB	SB(PD)
BENZ	BREMEN	WB	WB	SB	2K
	SINDELFINGEN	WB	WB	SB	2K
	RASTATT	WB	SB	WB	2K(WB)
OPEL	BOCHUM	WB	WB	WB	SB
	RUESSELSHEIM	WB	WB	WB	SB
	EISENACH	WB	WB	(RWB)	SB(WB)
VW	WOLFSBURG	WB	WB	WB	2K
	EMDEN	WB	WB	WB	2K
	HANNOVER	WB	SB	SB	SB
	ZWICHAU	WB	SB	SB	SB
AUDI	NECKARSULM	WB	SB	WB	SB
	INGOLSTADA	WB	SB	WB	SB
FORD	KOELN	WB	SB	SB	SB
PORSCHE	STUTTGART	WB	SB	SB	SB

\* SB : Middle solid or solid solventborn

† 2K : two component urethane

‡ WB : water-based system(RWB: recycling water-based system)

§ PD : powder dry paint system

4.72 ppm, 1.10 11.57 ppm  
가  
2-ethoxy ethanol, 2-ethoxy  
ethyl acetate가  
가  
2,4 TDI가  
2.  
가  
2-ethoxy ethanol, 2-ethoxy ethyl  
acetate, toluene, methyl isobutyl ketone,  
butyl acetate, ethyl benzene, xylene(m, o, p),  
toluene, trimethyl benzene(123, 124, 135) ,  
xylene, ethyl benzene, ethyl methyl benzene,  
trimethyl benzene, ethyl acetate, butyl  
acetate, methyl isobutyl ketone, 2-ethoxy  
ethanol, 2-ethoxyethyl acetate, toluene  
-2,4-diisocyanate(2,4 TDI)가  
2-  
butoxyethanol, 2-heptanone  
14.88 ppm, 7.48 19.12 ppm) 4.  
2-butoxy ethanol  
가  
3.  
가  
2-ethoxy ethyl acetate, toluene, methyl  
isobutyl ketone, butyl acetate, ethyl acetate,  
ethyl benzene, xylene(m, o, p)  
2-butoxy ethanol 2-heptanone  
가  
27.76 ppm, 15.79  
35.36 ppm) 가  
, butyl acetate(  
21.82 ppm, 11.71 28.83ppm)가  
m-xylene( 10.96 ppm, 5.9  
6 14.34 ppm)  
acetate( 24.54 ppm, 11.56  
32.59 ppm)가 가  
2-butoxy ethanol  
, m-xylene( 17.86  
6.91 ppm, 5.73 7.92 ppm  
2-butoxy ethanol  
4.  
2-butoxy ethanol



가 1999; 9(1):112-124

1998; 8(1):105-114

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1999; 188, 189, 190

96-31- ; 1996

3 ( ) ( ) ; 1999

Ethylene Glycol Ethers 가.