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A Small Chamber Test and Oddy Test on Medium Density Fiberboard grade (E0, E1)

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Abstract
Careful consideration needs to be taken when the museum display cases are selected. Materials used in the production of showcases should satisfy its standard uses in museums. Recently, the uses of Medium Density Fiberboard (MDF) E0 and Medium Density Fiberboard E1 in the construction of a display case and exhibition areas have been increased in Korea. This report is to investigate the suitability of these two different fiberboard to house museum's objects. Small environmental chamber test was used to measure the different emission levels of the gases; formaldehyde and acetaldehyde from MDF E0 and MDF E1. Then, the Oddy Test was used to measure the impact of these gases: formaldehyde, acetaldehyde. In order to do the test, the small metal samples are prepared: Silver, Iron, Copper, and Lead.

In the small chamber test, the level of formaldehyde was measured lower in MDF E0 than MDF E1. However, the level of acetaldehyde was measured higher in MDF E0 than MDF E1. The results of Oddy Test showed the samples tested with acetaldehyde have been damaged more than the ones with Formaldehyde. Especially, Iron, Copper, Lead were more damaged by acetaldehyde than formaldehyde in the level of their discoloration and corrosion. The fact that the emission levels of these gases are likely to be much higher (approximately 120 times higher) in a air-tight display cases (air change rate: 0. 004/hr = 0.1/day) than in a small environmental chamber (air change rate: 0.5/hr =12/day), which used in this investigation. This implies that MDF E0 could cause undesirable impart to the objects than MDF E1. This tells us that MDF E0 could cause undesirable impacts to the objects than MDF E1. Many questions need to be answered in the near future. Based upon this investigation, the authors wish to carry out continuous investigation in this matter.

1. Introduction

Recently, the uses of Medium Density Fiberboard (MDF) and plywood in the construction of a display case and exhibition areas have been increased in Korea. In this report, the impact of these materials to metal objects was investigated by measuring the emission levels of these two gases under the certain conditions.

The tested samples are: wood, plywood, MDF, and particleboard. Wood is divided into two groups that are: soft wood and hard wood. Plywood is made from the layers of soft wood of hard wood by adhering each layer in 90 degree with adhesives. MDF is made of a mixture of wood fibers. The density of the wood fibers is about 0.35 g/cm^3 ~ 0.85 g/cm^3, which is formed by pressing them with heat when they are mixed with various adhesives such as urea resin, urea-formaldehyde resin, phenol-formaldehyde resin. Particle board is a mixture of different particles of woods such as chips, flakes, wafer, and strand which would have been adhered together until it has the density of 0.5 g/cm^3 ~ 0.8 g/cm^3. [1), 2) ,3)]

In order to use wood and adhesives as an element of a showcase in museum, it should meet certain standards such as the pH level – the pH level of emmited acid gas from the wood should be above 5.0. The examples of standard adhesives are phenol-formaldehyde, poly-urea, epoxy resin and melamine resin[4)] (Jean Tetreault, 1993). It is, for instance, recommended to avoid using Oak as it emits acetic acid, which cause metal corrosion, discolouration on textiles and paper. Oak also cause a decay to an object containging calcuim. If there is no option than Oak, the wood board should be either coated or a barrier using PE+Aluminum shoule be applied[5)] (Jean Tetreault, 1999).It is also reported that the hardwood emits more acid gases than the softwood causing metal corrosion. The board made of using hardwood, the corrosion of iron and lead obejcts, for instance was serious and happened very radily. On the other hand, Copper and Silver obejcts did not show serious corrosion. The board that produced using adhesive, which are Carbamide resin, Phenol resin, did not emits any acid gases[6)](Gunnel Werner). Hannah Lane, in her study of the conservation and storage of the lead coins, mentioned that the corrosion of the coins was caused by its storage conditions rather than the obejcts itself such as residues of chemicals that used during conservation treatments[7)].

The recent study on MDF mentioned that the properties of MDF can be affected by the length of wood fibers as it can also decide the amount of adhesives used in the production process. For example, the hard wood has shorter fibers than the soft wood requiring more adhesive to produce a board. In gerneral, the hard wood with low pH level can produced the strongest boards when urea-formaldehyde resin is used. However, it is understood that the board made from mixing the fibers of the hard wood and the

soft wood with Phenol-formaldehyde resin would be the most suitable in term of conservation use [8] (Park,2001).

There have been many studies on the environmental issues and the suitability of the materials used in the construction of the display and storages of the museums. The author of this report have conducted the experiments by referring those existing studies on the corrosion of the metal objects caused by the wood, plywood, and MDF. This investigation tries to look at the characteristics and levels of the gases emitted from wood, plywood and MDF.

2. Material and Methods

2.1. Materials

In the Oddy test, three kinds of plywood, four kinds of MDF and six kinds of wood samples were prepared. The grade and the thickness of the samples are also mentioned. Prepared wood samples are Oak, Maple, Beech, Hemlock, Cherry, Ash. The details is listed in the table 1 and 2.

Table 1 . list of the samples of wood-based prouducts and woods for Oddy test

Test No.	Sample types (grade, thickness)	Size
wood-based products First	Plywood A(F0,15mm)	17mm×17mm
	Plywood B(F0,15 mm)	16mm×16mm
	Plywood C(F2,15 mm)	16mm×16mm
	MDF A(E0,15 mm)	14 mm×14 mm
	MDF B(E0,18 mm)	11 mm ×11 mm
	MDF C(E1,18 mm)	12.5 mm ×12.5 mm
	Blank	-

Wood Second	Oak (15 mm)	14 mm ×14 mm
	Maple (15 mm)	12 mm ×12 mm
	Beech (15 mm)	13 mm ×13 mm
	Hemlock (15 mm)	17 mm ×17 mm
	Cherry (15 mm)	16 mm ×16 mm
	Ash (15 mm)	12.5 mm ×12.5 mm
	Blank	-

Table 2. Samples of wood-based products for Small test chamber

Sample type (grade, thickness)	Size
MDF *(E2,9 mm)	115 mm ×115 mm
MDF B(E0,18 mm)	100 mm ×100 mm
MDF C(E1,18 mm)	100 mm ×100 mm
MDF A(E0,15 mm)	115 mm ×115 mm
Plywood A(F0,15 mm)	115 mm ×115 mm
Plywood B(F0,15 mm)	115 mm ×115 mm

2.2. Methods

2.2.1. Oddy test[9)]

The wood (Six) and wood based samples (three plywood and four MDF) for the Oddy test were cut into the certain size and their weight are about 2.0g (Photo 1, 2), then the samples were wrapped with aluminum foil. Four samples of same wood were placed in each test tube (50 ml). 5ml vial with the 0.5ml of distilled water, which was sealed with cotton (0.02g) was placed in the test tube, too. Metal samples: Ag, Fe, Cu, Pb were cut into the size of 10mm x 15mm(thickness 0.1 mm) and a hole with the size of 1.7mm was made on a sample below 3mm from the top of the sample. Next, prepared samples were immersed in acetone for 30min. After dring the samples in air, each sample was weighed and wrapped with alumium foil. The prepared metal samples were conneted to the glass lid of the glass bottle with Nylon thread. The gap between the lid and glass bottle were sealed with teflon tape. The same methods was applied to the wood and wood based samples. Finally, all prepared samples were placed into a dry chamber. The machine was heated upto 60ºC for 28 days (Fig.1). All samples were then taken out, weighted and monitored for any changes (photo 3-6).

2.2.2. Small test chamber[10),11)]

The sides of two plywood samples and four MDF samples, which were cut into the size of 115mmx115mm, were coated with paraffin. Then, these samples were placed in a 15.5l of a glass desiccator. A machine that measures temperature and humidity was placed in the same glass desiccator, too. Another machine was placed in an empty galss desiccator. This was prepared to compare the results from the different desiccator. These glass desiccator was vacuum-sealed and only 130ml/min of air was allowed. This was done using Pump and manifold. The temperature and humidity were kept in a constant level, which was 25±1ºC, 50%±5% (Fig. 2, Table 3). The air kept in the glass desiccator was collected in intervals - the first day, the second day, the third day, the forth day and the seventh day - In order to measure the level of any emitted gases, a 2,4-DNPH cartridge was placed on collected air for 250min with 60ml/min and the 2,4-DNPH cartridge was filtered with Acetonitrille solution. Later, the solution was analyzed with HPLC (Table 4).

Table 3. Experimental condition of chamber test

Items	Chamber test condition
Chamber Material	Glass desicator
Chamber Volume	0.0155 m^3
Sample Dimension	132.25 cm^2
Air Flow rate	0.00775 m^3/hr
Air exchange rate	0.5/hr
Loding Factor	1.7 m^2/m^3
Temperature	25±1ºC
RH (%)	50±5%

Table 4. Conditon of HCHO Analysis

Items	Experimental condition
System	HPLC waters 2690
Column	Symmetry C18 5μm (3.9×150mm)
Eluent	Isocratic 45/55 Water/Acetonitrile
Flow rate	1.0ml/min
Detection	UV at 360nm
Temperature	25ºC

3. Results

3.1. Oddy test

wood-based products

After conducting the oddy test for six different wood-based samples, the surface of the iron sample and the lead sample were covered with corrosion products. Some level of discoloration was observed on the surface of the copper samples. On the surface of the sliver sample, light pinkish colour was seen. Especially, the iron sample was the one with the most serious corrosion on the surface. Whitish corrosion products were seen on the surface of the lead sample. The silver, the iron, and the lead samples that tested for the comparison did not show any changes except the copper sample, which shows a light level of discoloration. Considering changes in discoloration and corrosion level, plywood showed more changes on four metal samples except M-B condition (Photo 7-14, photo 26-29).

(Observation)
Ag : M-B>P-C>P-A>P-B>M-C>M-A>Blank
Cu : M-B>P-C>M-A>P-B>M-C>P-A>Blank
Fe : M-B>P-C>P-B>P-A>M-C>M-A>Blank
Pb : M-B>P-B>P-C>P-A>M-C>M-A>Blank

(Changes in weight)
Table 5. shows the changes in the weight of the metal samples before and after the Oddy test.Iron samples have had increased its weight upto 20-50% and lead samples have had increased 1-21% in its weight. Some silver and copper samples have decreased its weight very slight. The highest weight gain was seen on the iron and the lead samples under the condition of M-B. The iron sample increased its weight upto 60.53% and the lead sample increased it weight upto 21.74%. The lowest weight gains of these two metals were made under the condition of M-A, which were 21.6% for the iron sample and 1.05% for lead sample. Except M-B condition, plywood have caused more serious impacts to the four different metals as they corroded more than other conditions
(Table 5, Fig. 3-4).

Fe : M-B>P-C>P-B>P-A>M-C>M-A>Blank
Pb : M-B>P-B>P-C>P-A>M-C>M-A>Blank

Woods

After conducting the Oddy test for the six different wood samples, the surface of the iron and the lead samples were covered with corrosion products. Some level of discoloration was also observed on the other samples. In the case of the sliver sample, light pinkish colour was seen. Especially, the iron samples were the ones with the most serious corrosion on the surface. Whitish corrosion products were seen on the lead samples. Silver and iron samples that tested for the comparison did not show any corrosion except the copper sample that shows a light level of discoloration. The lead samples show a slight corrosion on the surface. Considering changes in the coloration and corrosion level, the copper sample under W-O (Oak) condition was the one with the most discolouration. The iron sample and the copper sample under the same condition was the ones with the most corrosion on the surface. Silver, Cupper, Iron and lead under the condition of W-A (Ash) shows the least changes in their colouration and corrosion (Photo 15-22, Photo 26-29).

(Observation)

Ag : W-A>W-M>W-O>W-B>W-C>Blank>W-H

Cu : W-O>W-M>W-B>W-C>W-H>W-A>Blank

Fe : W-O>W-C>W-M>W-H>W-B>W-A>Blank

Pb : W-O>W-M>W-C>W-B=Blank>W-H>W-A

(Weight changes)

Table 5. Shows changes in the weight of the metal samples before and after the Oddy test. Among six different wood samples, the iron samples have had increased their weight up to 51%~59% and the lead samples have had rarely increased in there weight (0.5~1%). Some silver and copper samples have changed their weight slightly. The highest weight gain of the iron sample and the lead sample were made under the condition of W-O; 58.97% increase for the iron and 0.5-1.1% for the lead. The lowest weight gains of these two metals were made under the condition of W-A; 51.64% for the iron and 0.52% for the lead. Under the condition of W-H, the changes in the weight of the iron and the lead samples showed a slight increase (Table 5, Fig. 3-4).

Fe : W-O>W-C>W-M>W-B>W-H>W-A>Blank

Pb : W-M=W-B>W-C>W-O>W-A>W-H>Blank

Table 5. Weight Changes in Metal samples

Condition/ Samples	Percentage in the weight changes (%)			
	Ag	Cu	Fe	Pb
P-A	0	-0.78	51.61	3.72
P-B	0	0	53.33	12.77
P-C	-0.64	-0.78	53.78	8.25
M-A	-0.64	0	21.60	1.05
M-B	0	-0.78	60.53	21.74
M-C	0	-0.78	46.28	3.02
Blank	-0.67	-0.84	0.81	0
W-O	-0.63	0	58.97	2.56
W-M	0	0.76	53.72	3.17
W-B	-0.67	0	52.00	3.17
W-H	-0.65	0	51.69	2.54
W-C	-0.64	0	55.17	2.72
W-A	0	0	51.64	2.55
Blank	4.90	0.84	0	2.03

3.2. Small test chamber

Direct Calculation of Emission Factor from Individual Concentration Data Points

$$\mathbf{EF = (Ct – Ctb) \times N/L}$$

Where:

EF = emission factor, $mg/m^2 \bullet hr$,

Ct = chamber concentration at time t, $\mu g/m^3$,

Ctb = blank chamber concentration at time t, $\mu g/m^3$,

N = air change rate, 1/hr, and

L = loading factor, m^2/m^3

Table 6. Measured HCHO , CH_3CHO concentration

Condition	Aldehyde	μg/m³					EF
		1day	2day	3day	4day	7day	mg/m²•hr
P-A	HCHO	-	6.12	11.02	11.02	12.24	0.0030
(F0)	CH3CHO	1.8	0	0	1.8	1.8	0.0005
P-B	HCHO	-	-	-	-	-	-
(F0)	CH3CHO	3.59	5.39	-	7.18	1.8	0.0013
M-A	HCHO	48.98	48.98	41.63	45.31	40.41	0.0133
(E0)	CH3CHO	12.57	10.78	7.18	7.18	3.59	0.0024
M-B	HCHO	7.35	0	0	0	9.8	0.0013
(E0)	CH3CHO	168.82	122.12	96.98	96.98	89.80	0.0446
M-C	HCHO	193.47	184.90	-	164.08	186.12	0.0706
(E1)	CH3CHO	26.94	14.37	-	8.98	8.98	0.0057
MDF	HCHO	361.2	345.3	349.0	356.3	346.5	0.1034
(E2)	CH3CHO	9.0	3.6	7.2	5.4	10.8	0.0021

In general, the emission levels of formaldehyde and acetaldehyde in plywood P-A and P-B were lower than MDF. In the case of MDF, the emission levels of formaldehyde can be summarized as followed: M-B<M-A<M-C<MDF E2, which is related to their grades. Nevertheless, the emission levels of acetaldehyde from MDF show a different pattern. (Table 6, Fig. 5)

Formaldehyde MDF E2 >M-C>M-A>P-A>M-B

Acetaldehyde M-B>M-C>M-A>MDF E2>P-B>P-A

4. Conclusions

1. The result of the oddy test can be summerised as below:

Ag : light pinkish discolouration was seen on few samples but in general , Silver samples were rarely affected. There was only slight changes in their weight.

Cu: The copper samples were clearly affected as most of them have discoloured. But no significant changes in their weight.

Fe : The iron samples were the ones that most affected. Many samples have increased over 50% of their weight due to the corrosion products.

Pb: Whitish corrosion products were seen on many samples. The weight has increased as well.

The changes in the weights of metal specimen(Fe, Pb) after Oddy test ;

Woods - Fe(51~59%) , Pb(0.5~1.1%)

Plywood - Fe(51~54%) , Pb(3~13%)

MDF - Fe(21~60%) , Pb(1~21%)

Except M-B condition , Fe(21~46%) , Pb(1~3%)

2. The result of the Oddy test shows that the iron and the lead sample with the different wood samples shows a similar pattern in their weight changes. In the cases of plywood and MDF, several factors such as raw materials, adhesives, production line etc. could cause a difference in the weight of the same kind of a sample under the different conditions. Among metal samples, the iron samples increased their weight most. The order of the conditions that affect more to the corrosion of the iron samples is: M-B>W-O>W-C>P-B

3. Among the wood samples, Oak affects the iron sample most. On the other hand, Ash affects the iron sample least.
(Fe) corrosion : Oak > Cherry > Maple > Beech > Hemlock > Ash

4. MDF, which is produced using various mixtures of wood fibers, (plywood is produced using single boards attached by adhesives), although the levels of formaldehyde under the various conditions were low, emits the different levels of acetaldehyde under the various conditions.

5. Comparing the Oddy test on M-A, M-B, and M-C, the corrosion on the iron samples could be caused by the emission of acetaldehyde rather than the emission of formaldehyde.

6. The amounts of the emission of acetaldehyde and formaldehyde are likely to be much higher in air-tight case(air change rate: 0. 004/hr = 0.1/day), since the air exchange rate is lower than the one used in the experiments (small test chamber:0.5/hr=12/day). In the future, the conditions of the experiments should be drawn carefully so one can adapt the result more effectively. This can bring better controlling and monitoring of the museum environments for the display and storage.

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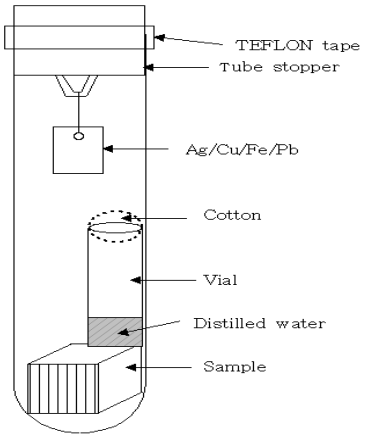


Fig. 1. Oddy test set

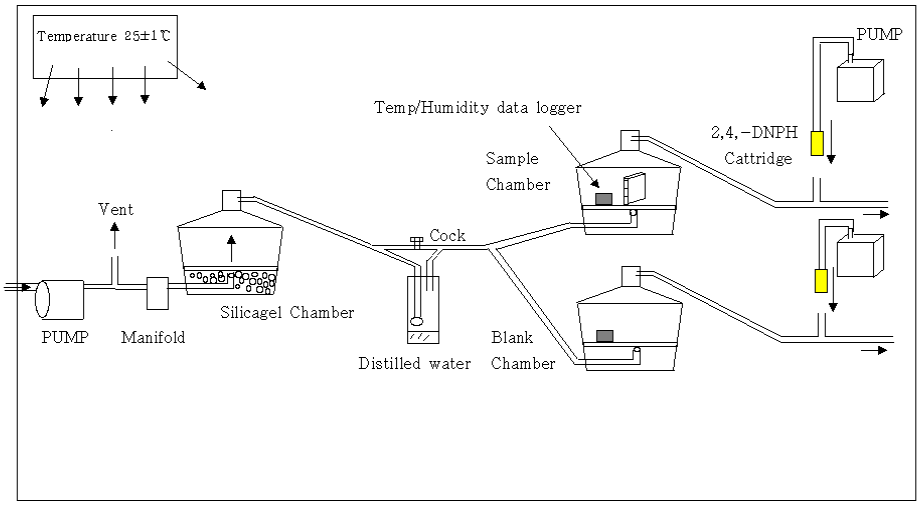


Fig. 2. Small test chamber set

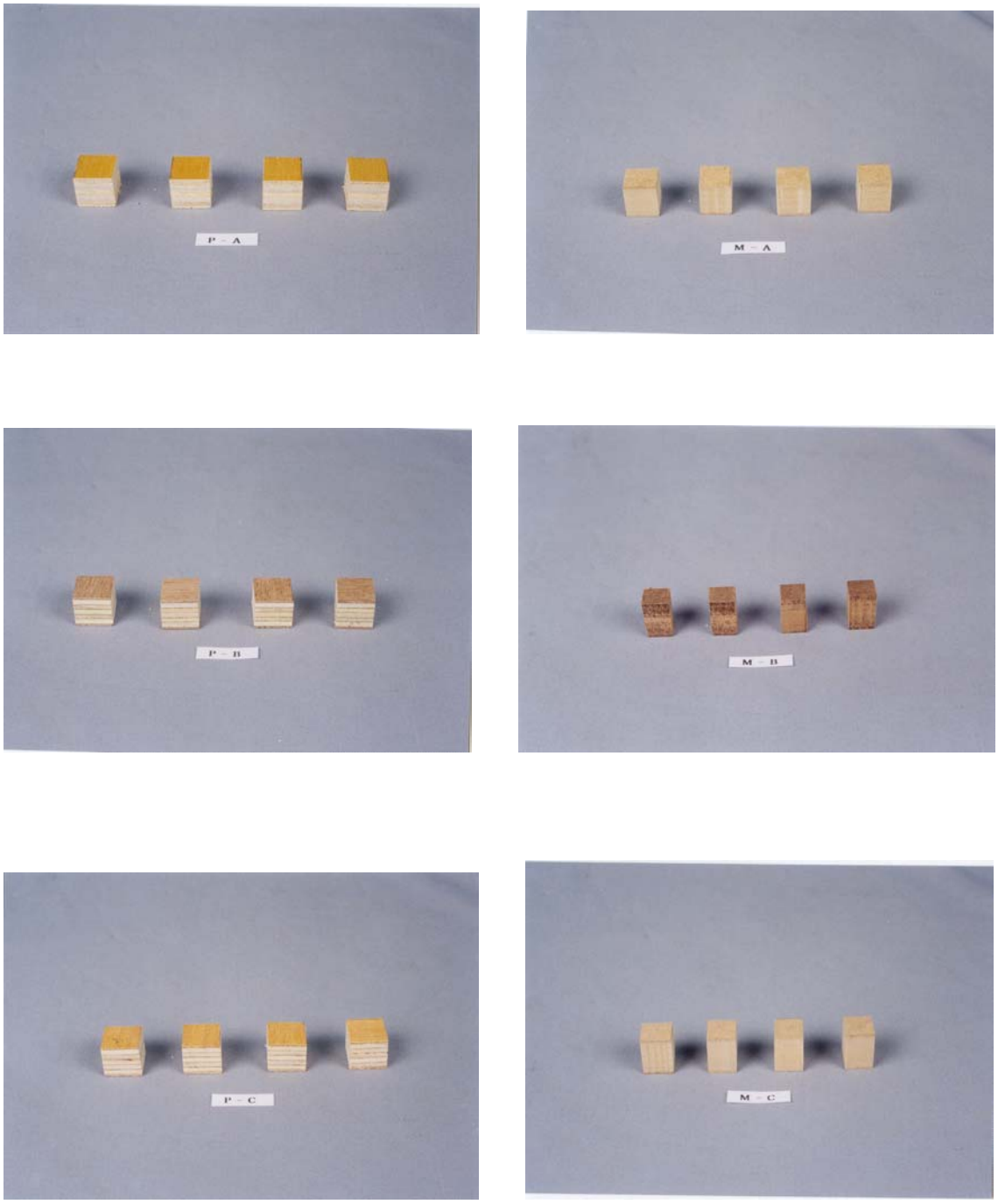


Photo 1. Wood-based product Specimens for Oddy test

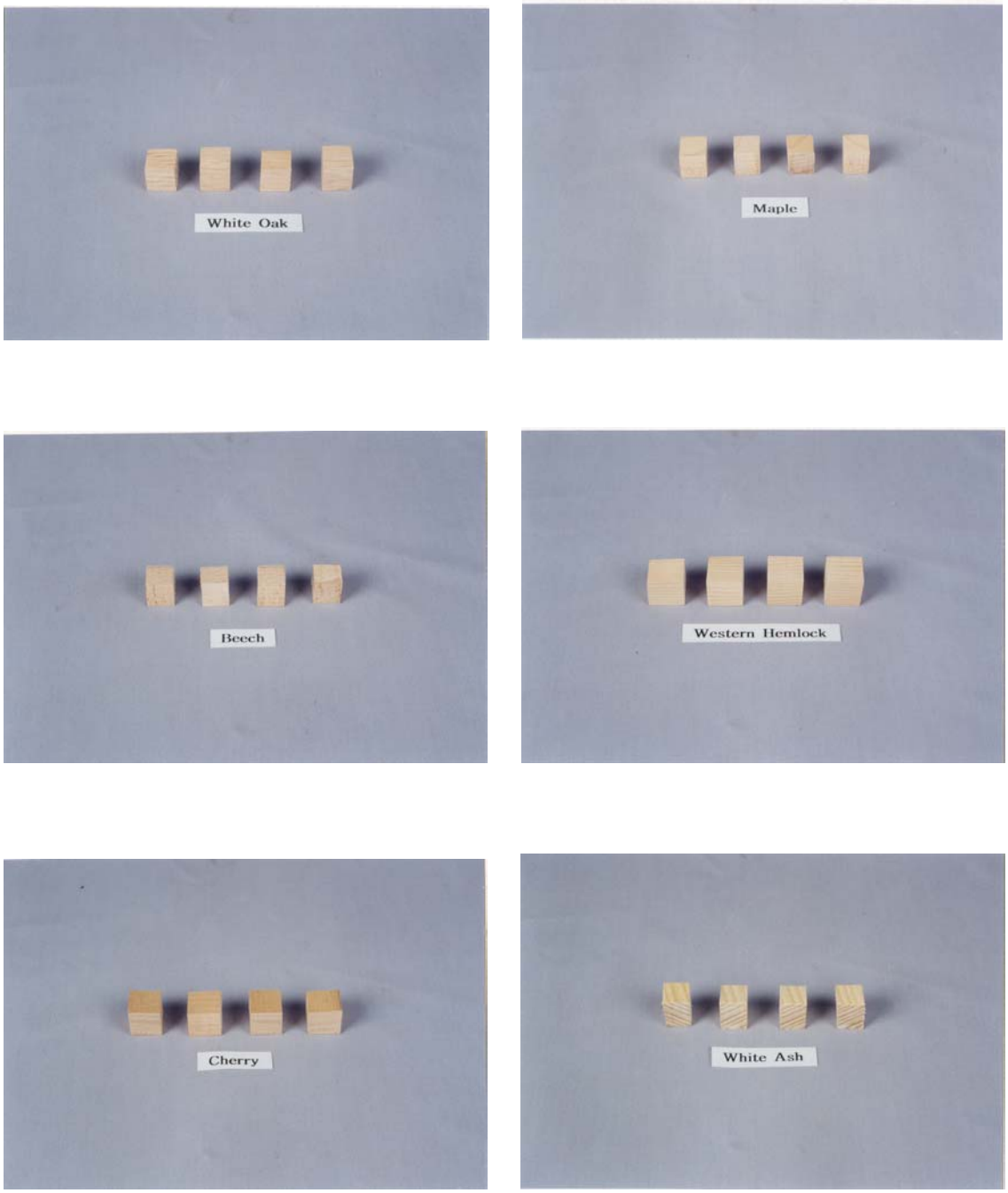
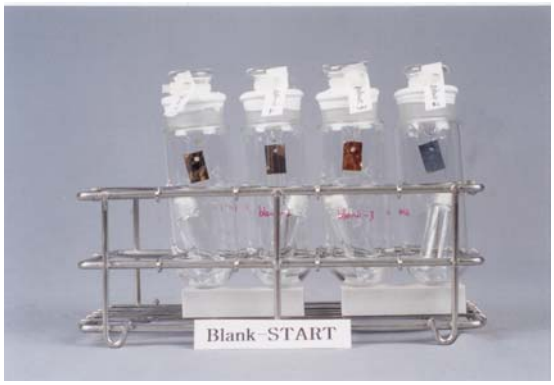


Photo 2. Woods specimens for Oddy test



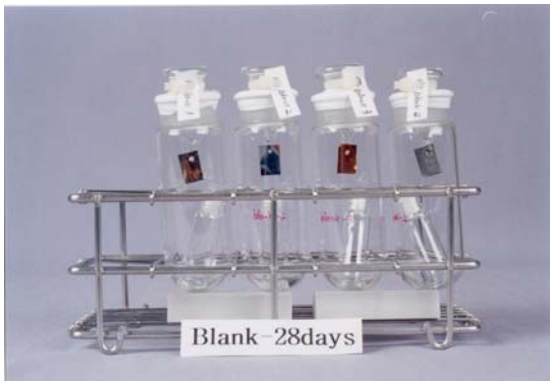


Photo 3. Blank test tube of Oddy test

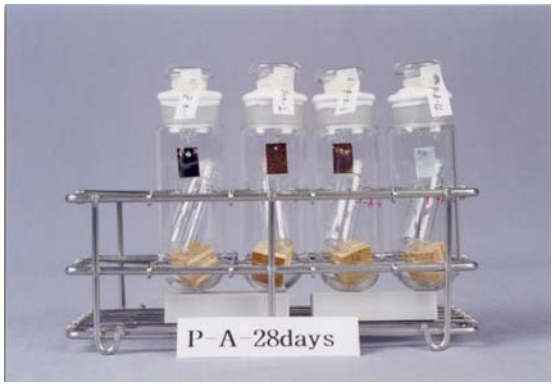


Photo 4. P-A test tube of Oddy test

Photo 5. Dry chamber

Photo 6. Weight Measurement

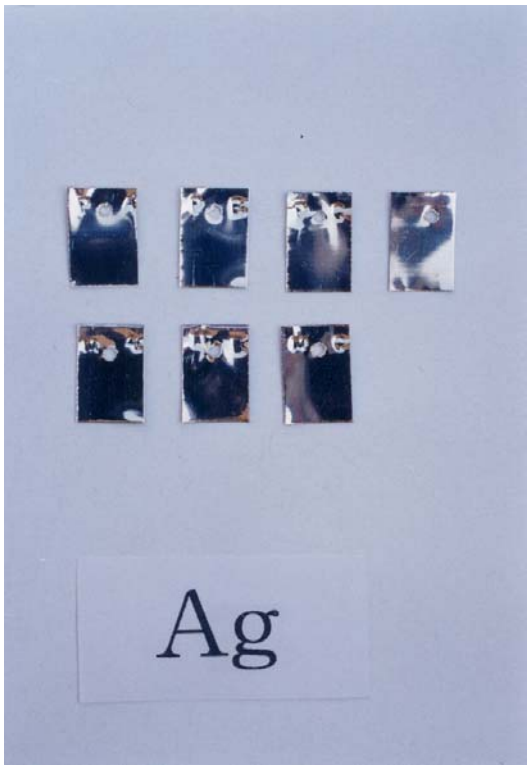


Photo 7. Before test (wood-based)

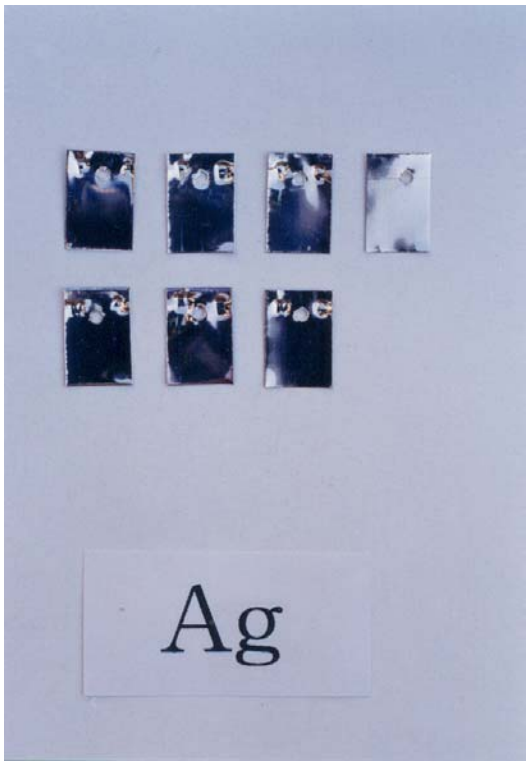


Photo 8. After test (wood-based)

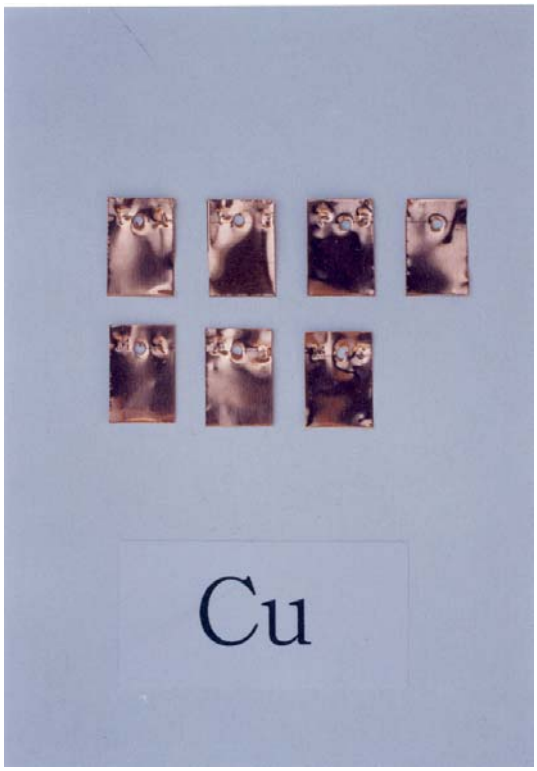


Photo 9. Before test (wood-based)

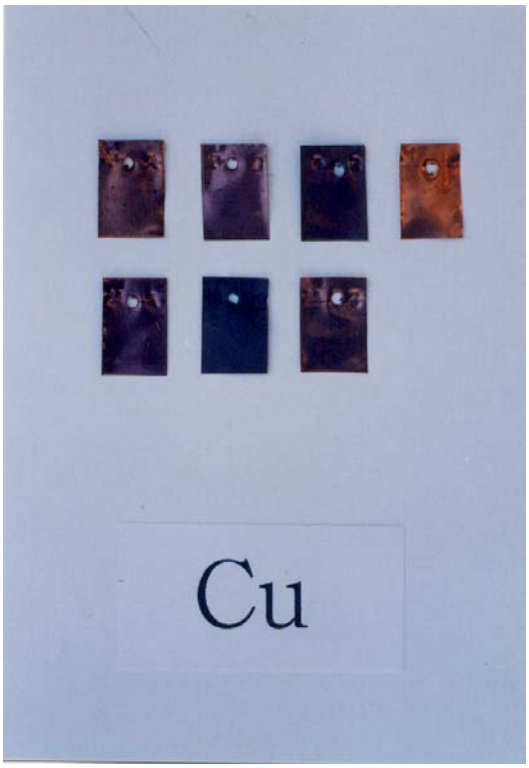


Photo 10. After test (wood-based)

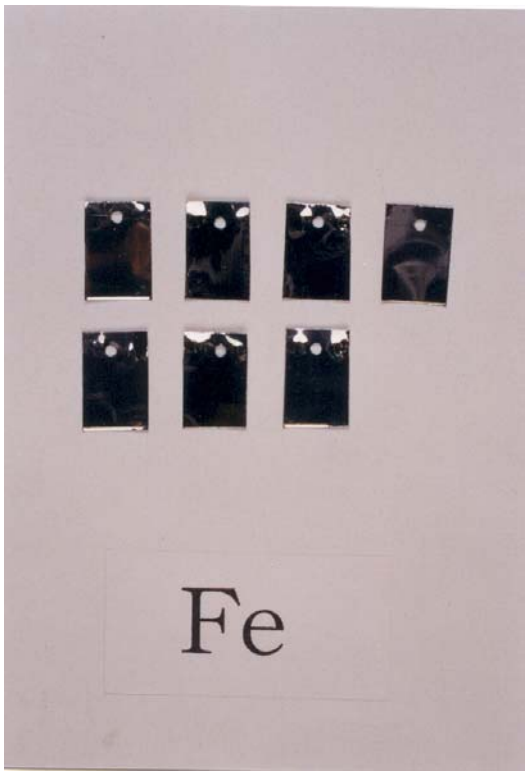


Photo 11. Before test (wood-based)

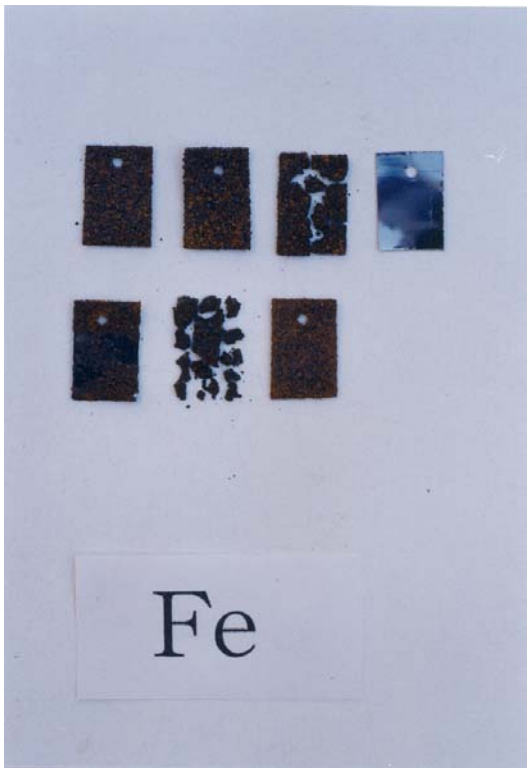


Photo 12. After test (wood-based)

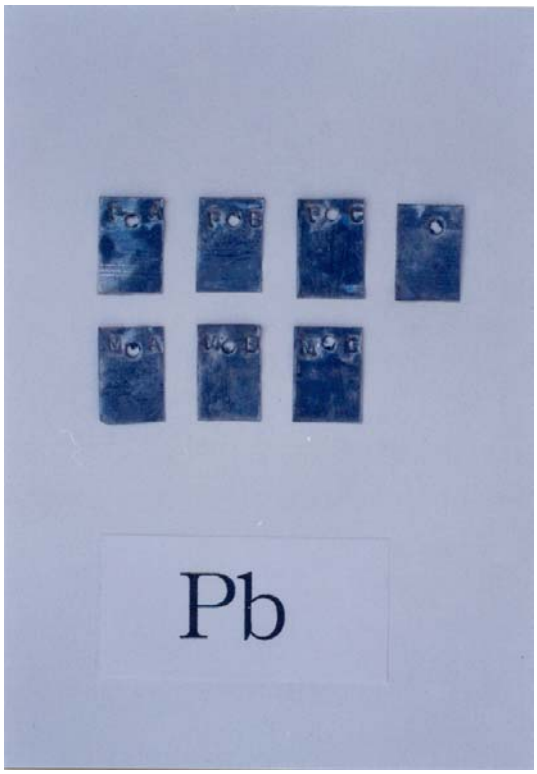


Photo 13. Before test (wood-based)

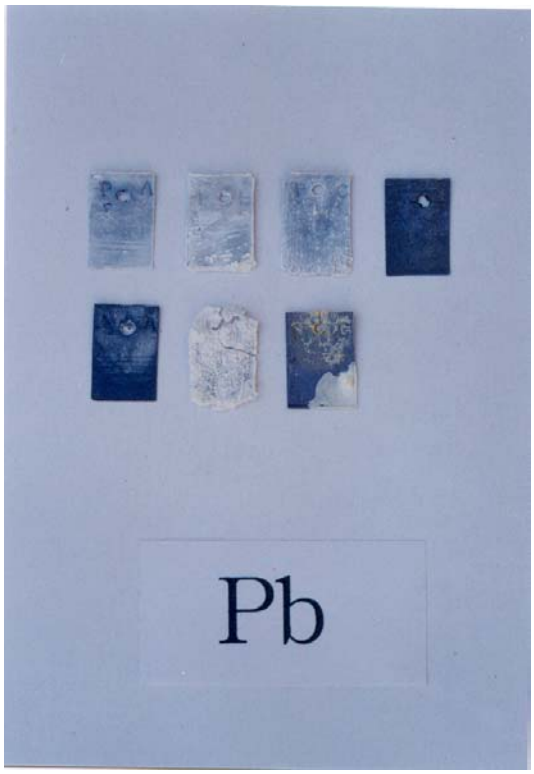


Photo 14. After test (wood-based)

Photo 15. Before test (wood)

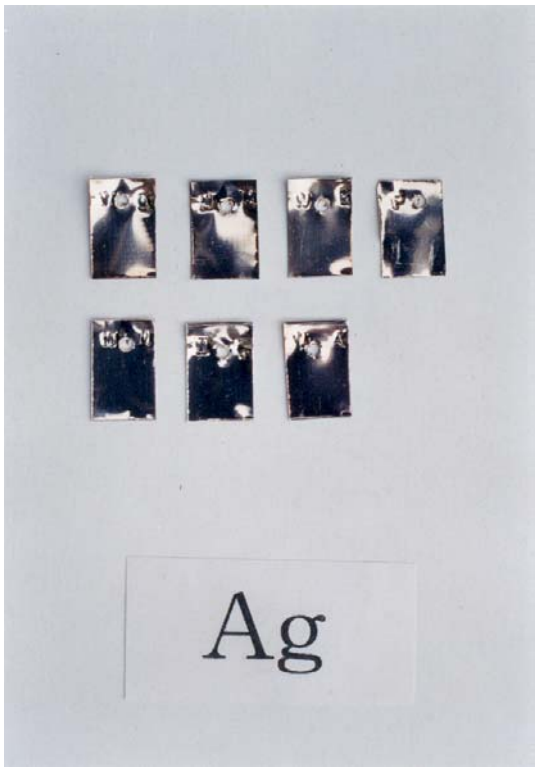


Photo 16. After test (wood)

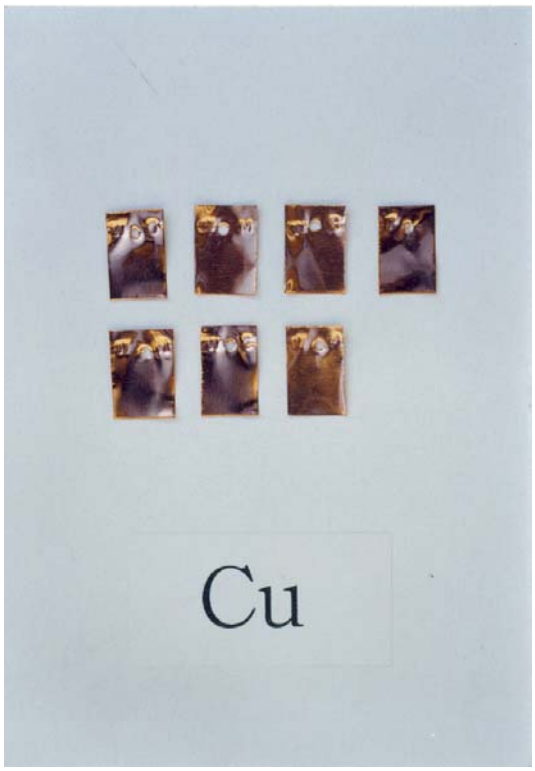


Photo 17. Before test (wood)

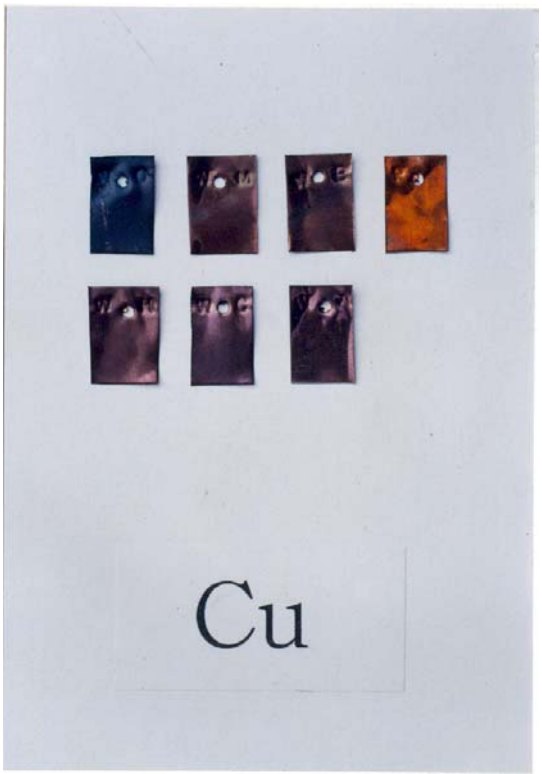


Photo 18. After test (wood)

Photo 19. Before test (wood)

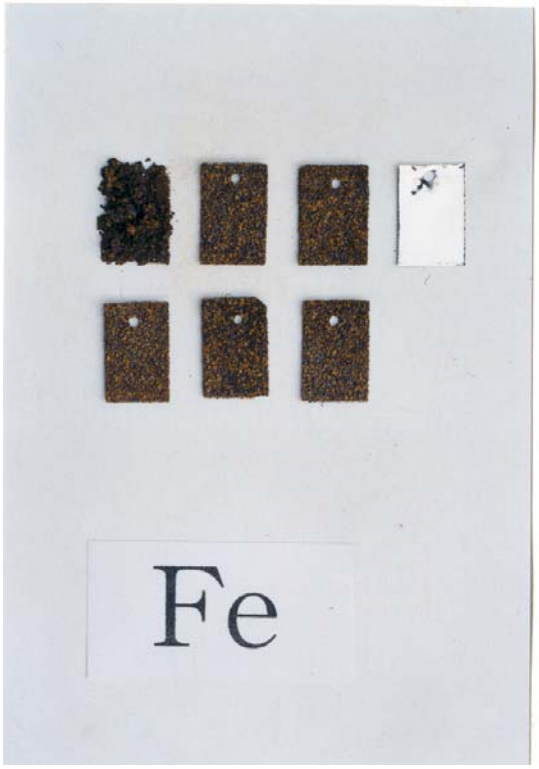


Photo 20. After test(wood)

Photo 21. Before test (wood)

Photo 22. After test (wood)

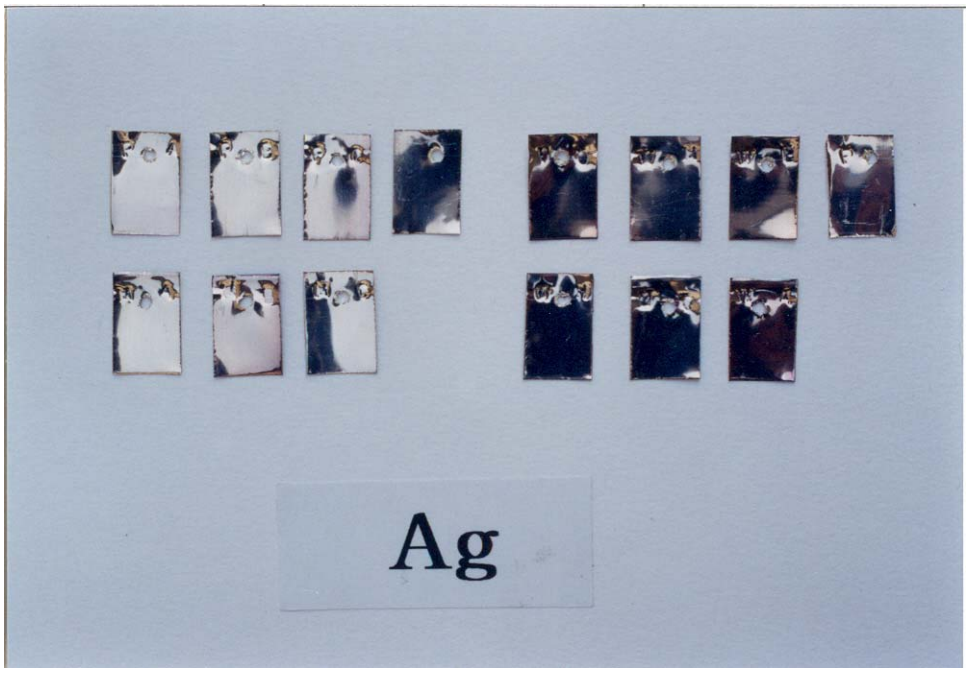


Photo 23. Comparison Ag(in wood-based products) with Ag(in woods)

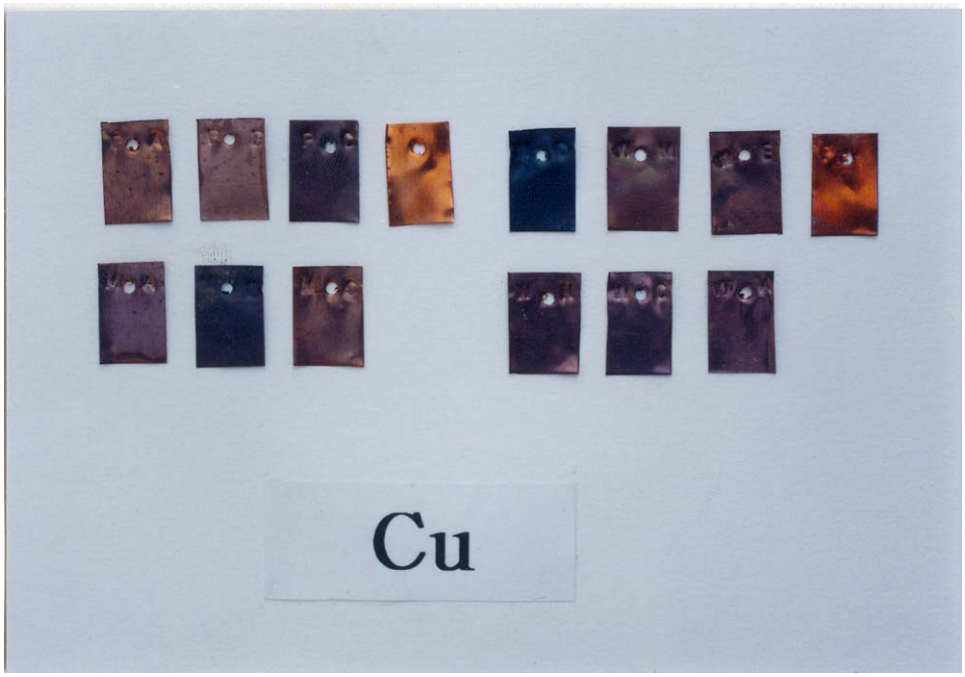


Photo 24. Comparison Cu (in wood-based products) with Cu (in woods)

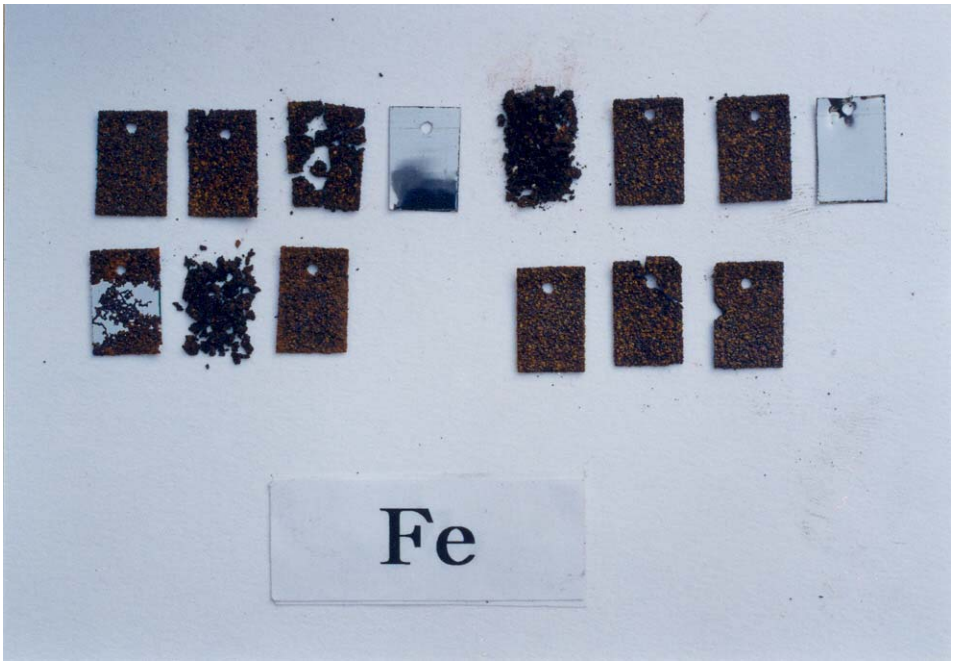


Photo 25. Comparison Fe(in wood-based products) with Fe(in woods)

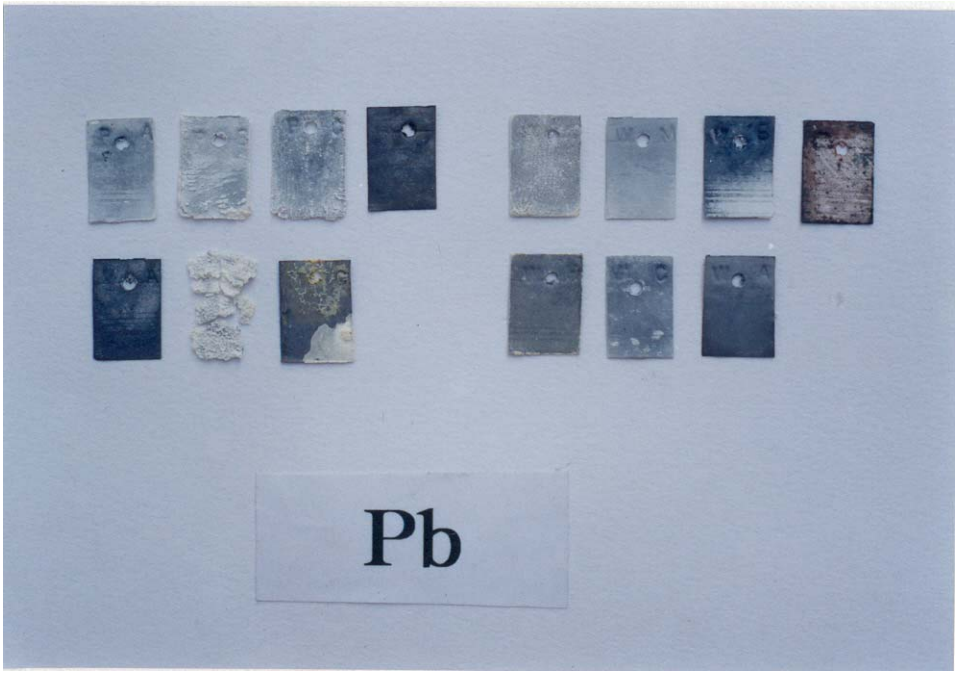


Photo 26. Comparison Pb(in wood-based products) with Pb(in woods)

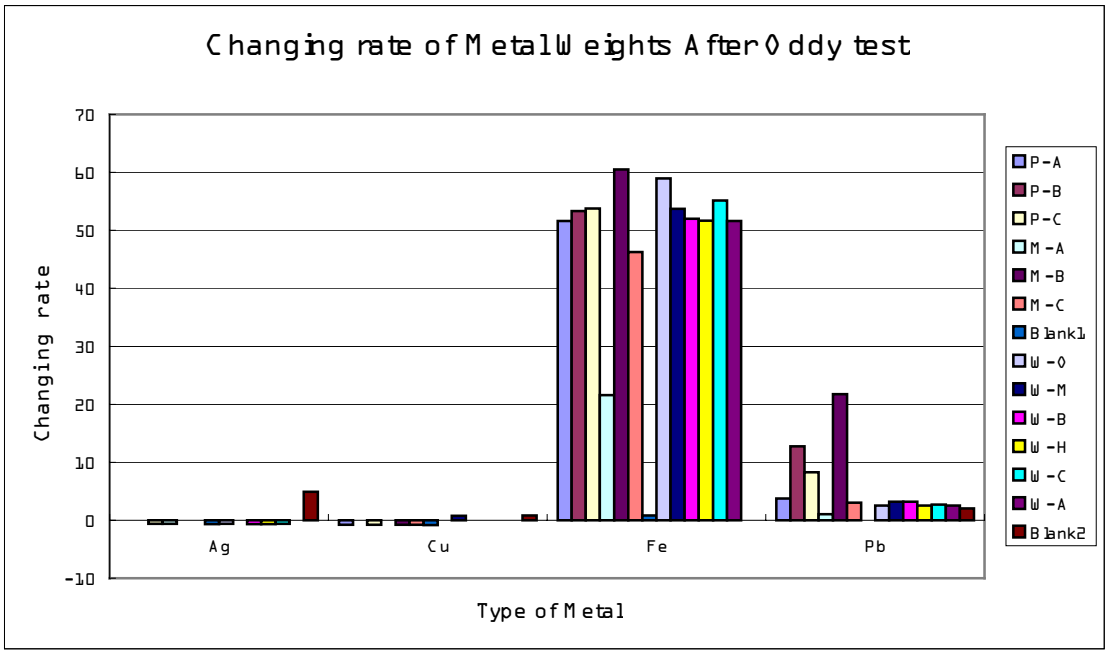


Fig. 3. Changing Weights rate of Metal on Woods and Wood-based products

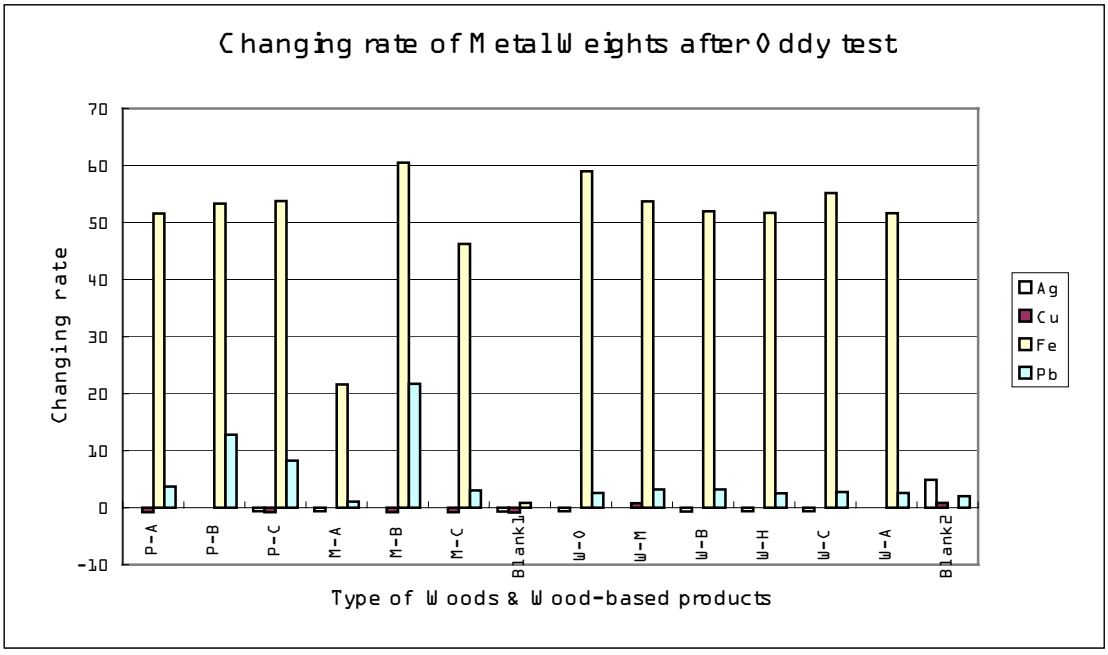


Fig. 4. Changing Weights rate of Metal on Woods and Wood-based products

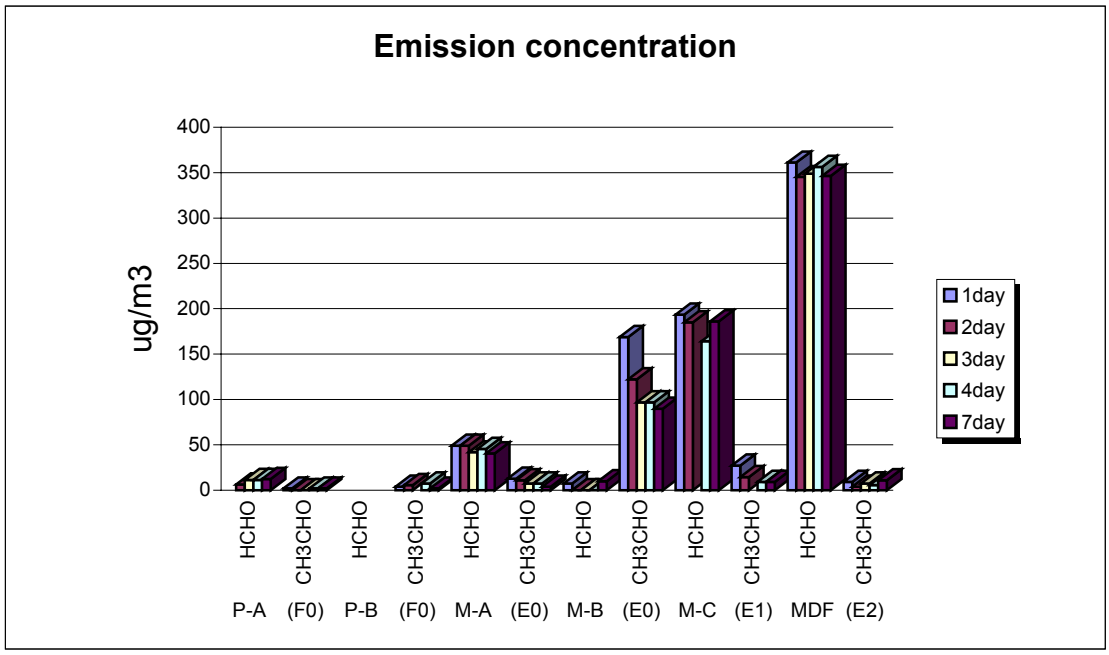


Fig. 5. Emission concentration of Woods and Wood-based products