

## MEASUREMENT OF VOC EMISSIONS FROM WOOD REMEDIAL TREATMENT: CHAMBER TESTS AND FIELD EXPERIMENTS

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### ABSTRACT

The purpose of this study is to document the impact of wood preservative products on indoor air quality. The emissions of two wood remedial treatment products (water-based and petroleum-based solvent formulations) representative of the market were characterized by two laboratories using emission test chambers. For most identified VOC, concentrations sharply decrease with time reflecting the solvent evaporation. VOC emissions from wood remedial treatment were also directly measured in real conditions during a roof renovation work in an old building. A petroleum-based solvent product was used by a professional applicator on the roof trussing. VOC were monitored up to 6 days after treatment. Identified VOC and emission patterns in test chambers and on the field are comparable. Emissions have been modeled and the models used to estimate the necessary time before re-entry in the treated space.

### INDEX TERMS

VOC, Test chambers, Field experiments, Wood remedial treatment, Emission modeling.

### INTRODUCTION

Standardized emission test chambers (CEN, 2001) represent useful and suitable methods for the determination of volatile organic compound (VOC) emissions from building products. Simple models can be applied to emission test chamber results in order to predict concentrations in real rooms. The purpose of this work was to differentiate the emissions of petroleum-based from water-based products using test chamber methods and to estimate the time before re-entry in the treated space after a wood remedial treatment operation using predictive models.

Previous studies presenting comparisons between emission test chamber results and concentrations measured in real rooms showed differences which can be significant (Zellweger, Gehrig, Hill *et al.*, 1995; Horn, Ullrich and Seifert, 1997; Dokka, Jorgensen, Bjorseth *et al.*, 1999; Köhler, Weis and Jastorff, 2000). The second purpose of this study was to make such a comparison in the case of wood remedial treatment.

### METHODS

Two wood preservative products representative of the French market have been selected for this study according to their respective solvent formulation: petroleum-based (PB) and water-based (WB).

Each test specimen was prepared with spruce tree boards previously conditioned at 23 °C and 50 % relative humidity (RH). Wood treatment was simulated in the laboratories by applying 300 ml.m<sup>-2</sup> PB or WB products on the spruce boards with a paintbrush. At CSTB, 3 layers

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were applied with 5 minutes interval while at CTBA, the 3 layers were applied with a 30 minutes interval. Samples were then conditioned in emission test chambers according to the new ENV 13419-1 standard (CEN, 2001). For CTBA experiments, prior to chamber conditioning, prepared specimen were stored in a ventilated cabinet during 90 or 60 minutes for PB and WB products respectively, to avoid any leaching in the chamber.

Test conditions selected by CSTB and CTBA in accordance with the ENV 13419-1 standard are presented in Table 1. The area specific air flow rate was chosen as representative of the surface of a frame in a roof trussing ( $1.5 \text{ m}^3 \cdot \text{h}^{-1} \cdot \text{m}^{-2}$ ). A reference specimen made of untreated wood was also studied in the same environmental conditions.

**Table 1.** Emission test parameters selected by CSTB and CTBA laboratories

| <i>Test parameters</i>      | <i>CSTB</i>   | <i>CTBA</i>   |
|-----------------------------|---|---|
| Test chamber                | Glass, $0.05 \text{ m}^3$ (CLIMPAQ)                       | Stainless steel, $1 \text{ m}^3$                          |
| Temperature                 | $23 \pm 2 \text{ }^\circ\text{C}$                         | $23 \pm 2 \text{ }^\circ\text{C}$                         |
| Relative humidity           | $50 \pm 5 \%$   | $50 \pm 5 \%$   |
| Air flow rate               | $0.6 \text{ m}^3 \cdot \text{h}^{-1}$                     | $0.6 \text{ m}^3 \cdot \text{h}^{-1}$                     |
| Test specimen surface       | $0.4 \text{ m}^2$   | $0.4 \text{ m}^2$   |
| Air exchange rate           | $12 \text{ h}^{-1}$                                       | $0.6 \text{ h}^{-1}$                                      |
| Loading factor              | $8 \text{ m}^2 \cdot \text{m}^{-3}$                       | $0.4 \text{ m}^2 \cdot \text{m}^{-3}$                     |
| Area specific air flow rate | $1.5 \text{ m}^3 \cdot \text{h}^{-1} \cdot \text{m}^{-2}$ | $1.5 \text{ m}^3 \cdot \text{h}^{-1} \cdot \text{m}^{-2}$ |
| Test duration               | 144 hours   | 144 hours   |

VOC sampling was performed using TENAX<sup>®</sup> TA after 2, 4, 6, 24, 48, 72 and 144 hours of specimen conditioning in test chambers. VOC analyses were then performed by thermal desorption and gas chromatography (GC) using mass spectrometry (MS) for identification and flame ionization detector (FID) for quantification according to the ISO/DIS 16000-6 draft standard (ISO, 2000). VOC were quantified using the toluene response factor. The total volatile organic compound (TVOC) concentration was defined as the sum of concentrations of identified and unidentified VOC eluting between hexane and hexadecane (included).

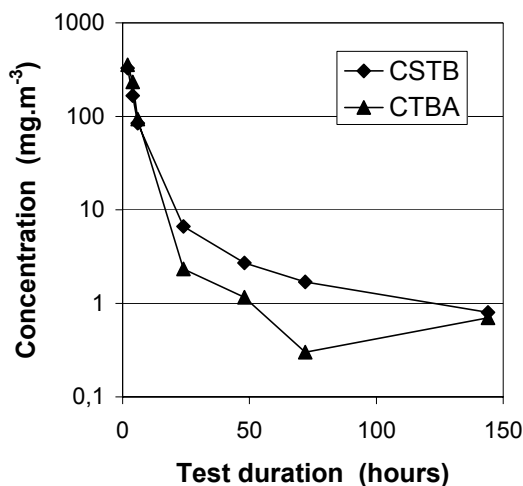
The selected analytical parameters on the GC were not optimal for the detection of the wood preservative active molecules (insecticide and fungicide) which are less volatile than VOC. Therefore, this study focuses on the characterization of VOC emissions of the solvent of wood preservative products.

For field experiments, a roof remediation work in an old building was selected. The wood preservative treatment was performed by a professional applicator spraying and injecting  $300 \text{ ml} \cdot \text{m}^{-2}$  of preservative product in the old oak frame. The roof trussing volume was  $65 \text{ m}^3$  and the wood surface to be treated was estimated by the applicator to be  $84 \text{ m}^2$ . Therefore, the loading factor was  $1.3 \text{ m}^2 \cdot \text{m}^{-3}$ . The wood preservative was a petroleum-based (PB) solvent product similar to the PB product tested in the laboratories. Field and laboratories sampling and analytical conditions were identical. Sampling has been performed prior to and 24, 72 and 144 hours after wood treatment.

At the end of field experiments, the air exchange rate has been estimated using sulfur hexafluoride ( $\text{SF}_6$ ) as tracer gas. We found that the treated space was highly ventilated (air exchange rate =  $20 \text{ h}^{-1}$ ) and made the assumption that ventilation conditions have been rather constant. From this estimation, we can derive the area specific air flow rate during field experiments ( $15.4 \text{ m}^3 \cdot \text{h}^{-1} \cdot \text{m}^{-2}$ ).

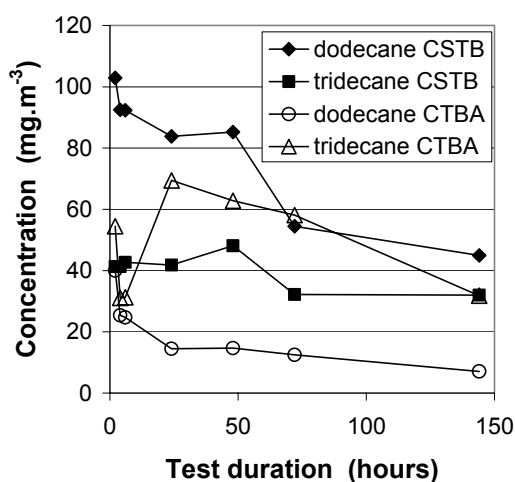
## RESULTS

As a reference, emissions of untreated spruce boards have been characterized after 72 hours. They are mainly dominated by alkanes (nonane, decane and undecane), cycloalkanes (propylcyclohexane and butylcyclohexane) and aromatic compounds (ethylbenzene and xylene). The TVOC concentration of the untreated spruce specimen is  $1.8 \text{ mg.m}^{-3}$  after 72 hours conditioning in CSTB emission test chamber.



**Figure 1.** 1-methoxy-2-propanol concentrations in CSTB and CTBA emission test chambers (log scale) for the water-based wood preservative.

Emissions of the water-based (WB) product are dominated by glycol ethers, mainly 1-methoxy-2-propanol and isomers of dipropylene glycol methyl ether. To a lesser extent, alkanes (from decane to tridecane) and aldehydes (mainly hexanal) have also been identified in test chambers. Emissions of the WB wood preservative decrease sharply during the first 24 hours of the test as illustrated on Figure 1 for 1-methoxy-2-propanol. Indeed for most identified VOC in test chambers, 24 hours concentrations range from 1 % to 10 % of 2 hours concentrations.



**Figure 2.** Dodecane and tridecane concentrations in CSTB and CTBA emission test chambers for the petroleum-based wood preservative.

The petroleum-based (PB) product emissions are characterized by very high concentrations of alkanes (from undecane to tetradecane), cycloalkanes (butylcyclohexane), aromatic compounds and terpenes (limonene and camphene). This solvent is mainly composed of molecules with 11 to 14 carbons. Emissions of the PB product are globally much higher than emissions of the WB product and VOC decrease in test chambers is less pronounced as illustrated on Figure 2 for dodecane and tridecane.

Before treatment, VOC levels in the roof trussing were rather low (TVOC = 0.12 mg.m<sup>-3</sup>) and traces of acetic acid, toluene and  $\alpha$ -pinene have been detected. After treatment, emissions were characterized by the evaporation of the organic solvent phase and dominated by alkanes (mainly dodecane, tridecane and tetradecane), alkenes and cycloalkanes. Qualitatively, VOC identified during field and test chamber experiments were directly comparable. The TVOC concentration in the roof trussing decreased from 24.5 mg.m<sup>-3</sup> 24 hours after treatment to 6.6 mg.m<sup>-3</sup> 144 hours after treatment.

## DISCUSSION

For both WB and PB wood preservative products, we found a reasonable agreement between results obtained by CSTB and CTBA laboratories in terms of identified VOC and emission patterns even if emissions measured by CSTB are generally higher. This can reasonably be explained by differences in test specimen preparation by both laboratories. For CTBA experiment, the higher interval between each layer's application and the specimen storage in a ventilated cabinet prior to conditioning has presumably caused an initial evaporation of the solvent and a lower VOC load introduced in the chamber.

In order to compare results obtained from chambers and field experiments, we have to consider the observed differences between specific ventilation rates in test chambers ( $q_C = 1.5 \text{ m}^3 \cdot \text{h}^{-1} \cdot \text{m}^{-2}$ ) and during field experiment ( $q_F = 15.4 \text{ m}^3 \cdot \text{h}^{-1} \cdot \text{m}^{-2}$ ). Therefore, we have calculated the TVOC concentrations in the roof trussing ( $C_{TVOCP}$ ) predicted from the concentrations measured in test chambers ( $C_{TVOC}$ ):

$$C_{TVOCP} = \frac{q_C}{q_F} C_{TVOC} \quad (1)$$

Then we have used a simple decay model (Dunn and Tichenor, 1988) to describe TVOC emissions of the PB wood preservative product in the emission test chambers and during field experiment. Modeled TVOC concentrations at time  $t$  can be expressed as:

$$C_{TVOCM} = \frac{k_1 A M_0}{V(k_2 - k_1)} [\exp(-k_1 t) - \exp(-k_2 t)] \quad (2)$$

where  $C_{TVOCM}$  is the modeled TVOC concentration (mg.m<sup>-3</sup>),  $k_1$  the emission rate constant (h<sup>-1</sup>),  $k_2$  the air exchange rate (h<sup>-1</sup>),  $M_0$  the initial TVOC load (g.m<sup>-2</sup>),  $A$  the treated surface (m<sup>2</sup>),  $V$  the test chamber or treated space volume (m<sup>3</sup>) at time  $t$  (h).

Parameters of TVOC emissions obtained with this model from test chamber and field experiments are presented in Table 2, with the initial emission factor  $EF_0$  (mg.m<sup>-2</sup>.h<sup>-1</sup>), defined as follows:

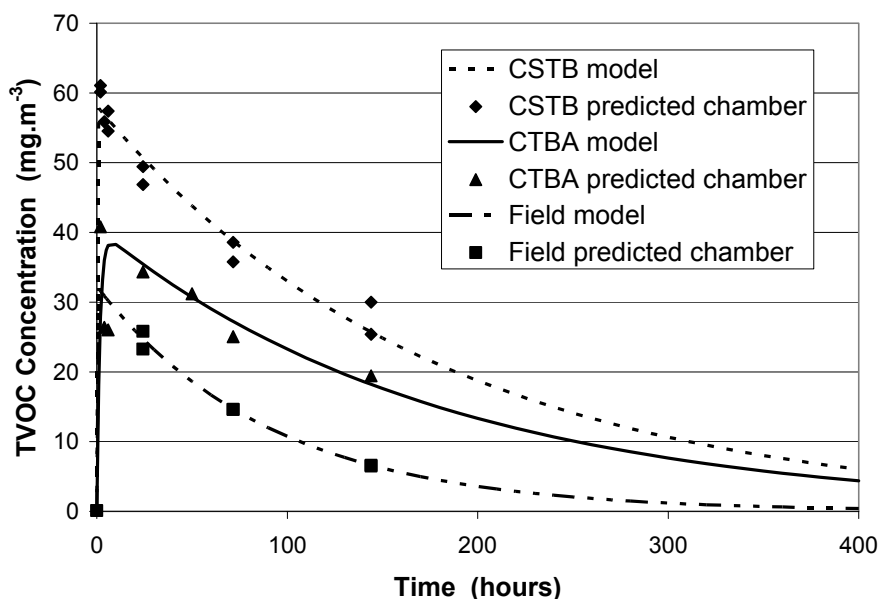
$$EF_0 = M_0 \cdot k_1 \quad (3)$$

**Table 2.** Model parameters for CSTB and CTBA chambers and field experiments

| Parameters                                  | CSTB  | CTBA  | Field exp. |
|---|-------|-------|------------|
| $k_1$ ( $\text{h}^{-1}$ )                   | 0.006 | 0.006 | 0.011      |
| $M_0$ ( $\text{g.m}^{-2}$ )                 | 160   | 110   | 45         |
| $EF_0$ ( $\text{mg.m}^{-2}.\text{h}^{-1}$ ) | 960   | 660   | 495        |
| Determination coefficient, $r^2$            | 0.95  | 0.97  | 0.99       |

Results of the model indicates that for both CSTB and CTBA chamber tests, the same emission behavior was observed since emission rate constants  $k_1$  are comparable, while the initial load  $M_0$  is higher for CSTB. This observation supports the hypothesis that a fraction of the solvent has been volatilized prior to introduction of the test specimen in the chamber for CTBA experiment. This is also illustrated on Figure 3, where we have plotted the predicted and modeled TVOC concentrations for CSTB and CTBA test chambers and for field experiment.

We found a reasonable agreement between chamber and field experiments even if  $k_1$  is higher and  $M_0$  lower during field experiment. This can presumably be explained by the difference in the product application simulated in the laboratories and really performed by spray and injection on the field. Diurnal temperature variations with high daytime values and air velocities in the highly ventilated treated space (air exchange rate =  $20 \text{ h}^{-1}$ ) may also explain those observations.



**Figure 3.** Predicted and modeled TVOC concentrations in CSTB and CTBA test chambers and during field experiment.

We have used this simple model and field experiment results to estimate time before re-entry in the treated space. The model indicates that 21 days are necessary before reaching the initial TVOC concentration before treatment ( $0.12 \text{ mg.m}^{-3}$ ) and only 3 days to reach the  $14.4 \text{ mg.m}^{-3}$  TVOC threshold proposed as non-professional exposure limit for white spirit (Orsler, Suttie and van Rijckaert, 1996). In case of lower ventilation conditions (air exchange rate =  $1 \text{ h}^{-1}$ ), the model estimation rises to 33 days and 15 days to obtain TVOC concentrations lower than the respective  $0.12 \text{ mg.m}^{-3}$  and  $14.4 \text{ mg.m}^{-3}$  values. Those estimations obtained from a single

and particular experiment should only be considered as indicative. They attest that particular precautions have to be taken during and after application of wood treatment products. Longer times are obtained if we use chamber results modeling.

## CONCLUSION

Emissions of wood remedial treatment products were characterized using emission test chambers. VOC concentration decrease in test chambers reflects the solvent phase evaporation dominated by C<sub>11</sub> to C<sub>14</sub> alkanes and cycloalkanes for a petroleum-based product and glycol ethers for a water-based product. VOC were also measured directly during a roof remedial work by a professional applicator using a petroleum-based product. A difference in the product application mode simulated in the laboratories and performed on the field is likely to explain the observed concentration differences between chamber tests and field experiment. Indeed, reproducible preparation of test specimen from liquid products appears as a major difficulty during laboratory inter-comparisons. Nevertheless, TVOC concentrations have been modeled and re-entry times after wood treatment have been tentatively estimated from this single field experiment for different ventilation conditions.

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