# HOLISTIC APPROACH TO REDUCING THE VOC EMISSIONS DURING THE APPLICATION OF VARNISH AT THE DEUTSCHE WERKSTÄTTEN

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## ABSTRACT

*The operators of varnishing facilities for wood and wood-based materials, among others, are obliged to meet application and operation-specific requirements and to reduce the emissions of volatile organic compounds (VOC) by the 31st German Federal Immission Protection Ordinance.*
*It was the goal of this paper to develop potential for savings by investigating production integrated reduction measures in due consideration of the high demand for quality of the surface coating regarding visual as well as mechanic-technological features of the DEUTSCHE WERKSTÄTTEN HELLERAU GmbH. The examinations showed that the highest potential of savings could be achieved by increasing the application efficiency factor of the spray guns.Ideal pressure settings as well as the correct use of the spreaders allow for significant savings of material. Furthermore, it has become apparent that a mechanic brush cleaning of the substrate surface can prevent failures in the subsequent coating. This, in turn, contributes to saving material and personnel expenditure.The consumption of solvent-containing detergents could also be reduced through the gradual elaboration of a new cleaning procedure. Finally, the examination of water-based two-component-polyurethane-varnishes through a sensory test procedure has proven watervarnishes of the newest generation equal to common solvent-containing varnishes in terms of the high quality requirements regarding the visual features. This opens up further promising possibilities to reduce VOC emissions.*
*In all points examined, from the viewpoint of work psychology the individual plays a crucial role as the executing worker for the impact of the respective reduction measure. This fact must be taken into account for the successful implementation of the production integrated measures.*

## 1. INTRODUCTION

To limit the emissions of volatile organic compounds (VOC); which, together with nitric oxides, are a precursor for the formation of ground-level ozone, the European cabinet enacted the directive 1999/13/EG to regulate the usage of organic solvents in certain facilities.[1]In 2001 the German law adopted the directive with the 31st German Federal Immission Protection Ordinance (31. BImSchV) and gradually implemented the aforementioned until the beginning of this year.[2]The new legal requirements forced solvent-using industries to a change of thinking, because the regulation specifically demands the use of low-solvent or solvent-free substances. Therefore, the operators of varnishing facilities were also affected, who, until then, used solvent-containing varnish systems for surface finishing.Ultimately, to meet the requirements the operators have the choice between using additional measures (cleaning of emissions) or production integrated measures.[3]. The DEUTSCHE WERKSTÄTTEN HELLERAU GMBH is also affected by the legal requirements of the

31st BImSchV. Within 20years,the company has built up a worldwide reputation for high-quality interior construction of prestigious residences, yachts and corporate spaces. Among the company's characteristic features is the finishing of real wood surfaces with a high-quality surface coating, which is also a factor crucial to the success of project planning. Highest quality requirements on mechanic-technological as well as visual and haptic substance properties of the varnish systems strongly decide on their application, due to the versatile locations of installation on land and water.
Additionally, the work pieces, which almost have no boundaries regarding material, form and size, require the usage of a manual spray coating method. The latter is considered suboptimal from an economic and ecologic point of view. Until now, these two parameters have prevented the application of low-solvent varnish systems or more efficient application systems.

## 2. Material and Methods

The prescribed legal underlying conditions, the quality requirements for surface coating of the Deutsche Werkstätten as well as exclusively the production integrated possibilities to reduce the application of organic solvents served as a foundation for the elaboration of possible reduction approaches. With regard to these parameters possible reduction measures were determined and examined using the following methods.

### 2.1.Surface Preparation

In the past, surface failures such as air locks and wood inclusions could be detected in the surface coating of veneers, mainly of tropical wood species, after the varnish had hardened.The necessary recoating due to such failures entailed considerable material and financial input. This examination was aimed at determining the impact of a mechanic surface preparation on the cleaning effect and the flow of the varnish. Samples were subsurfacescoated with Silky oak veneers *(ProteaceaeCardwelliasublimis*F Muell.*)*The cleaning effect of three sisal circular brushes of different hardness was examined, which were used on an angular plant. The subsequent coating of the sample surfaces was executed with a two-component-polyurethane primer (2K-PUR), which had been colored with two adsorption indicators.The visual analysis on a computer of the cleaning effect and the flow of the varnish was made possible with the help of a stereo microscope with electric image taking.

### 2.2. Application Efficiency Factor

The approach for the determination of the application efficiency factor (AEF) of the various spray guns was based on the VDMA standard sheet 24366 "Determination of the application efficiency factor for paint atomizers without electrostatic support". Not only was the examination aimed at determining the application efficiency factor for the hitherto set instrument adjustments, but also at determining the influence of optimized pressure settings and handling of spray guns on the application efficiency factor. Specially cut MDF samples served as a substrate for coating. They were then covered with aluminum foil, obtained from commercial trade. A 2K-PUR primer was used for the coating of the samples. All spreaders listed in Table 1 are frequently used in the process of coating.

*Table1: Tested spreaders for the determination of the respective AEF*

| Spray method | Spray gun |
|---|---|
| High Pressure (HP) | SATA LM 2000 |
| Reduced Pressure (RP) | SATAjet® 1000 B RP |
| High Volume Low Pressure HVLP | SATAjet® 2000 Digital HVLP |
| Hydraulically air-assisted | GRACO®Merkur, Pistole G 40 |

The aluminum foil was weighed with a micro scale before and after coating, with a drying time of five days in a trolley in the drying chamber at a temperature of 22±1 °C and a relative humidity of 45±5 %. The changes of the pressure settings following in Table 2 were implemented for the determination of the various AEFs.

*Table 2: Adjusted spray gun inlet pressure*

| Spray gun | Nozzle diameter [mm] | Spray gun inlet pressure old[bar] | Spray gun inlet pressure new [bar] |
|---|---|---|---|
| HP | 2 | 6 | 2.6 |
| RP | 1.8 | | |
| HVLP | 1.4 | | |

After the determination of the respective AEFs, the corresponding varnish saving rate could be calculated with the following equation 1.

$$\textit{Varnish saving rate} = 100x\left(1-\frac{A}{B}\right)[\%] \quad (1)$$

### 2.3. Cleaning of Spray Guns and Utensils

The reason for the following examination was the high loss of solvent-containing detergents in the cleaning process of spray guns and utensils. The aim of the new cleaning process for spray guns and utensils is the reduction of the amount needed and the decrease of the loss of detergents during the cleaning process. The weaknesses of the cleaning process regarding the automatic washing machine and the cleaning of spray guns and utensils at the spray station were to be remedied.
In collaboration with varnishers a gradual elaboration led to a definition of an expedient cleaning process and subsequently to the development of new cleaning methods. Thereby, a new circulatory cleaning process emerged. The usage of detergents in the new cleaning process was monitored in the course of 40 days at a representative workload and then projected to a potential annual consumption. Compared with the previous consumption of detergents, possible savings can be determined.

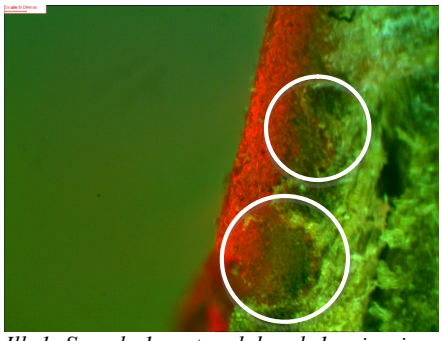
### 2.4. Water-based Varnish Systems

Previous attempts to include water varnishes into the coating program of the DW were attended by several prejudices regarding criteria of processing and visual features of quality. Besides the mechanic characteristics and the lack of certificates, the low-solvent coating substances also failed regarding visual features of quality such as gloss level, transparency, shine and especially the characteristic intensification of the wood surface. Yet, varnish manufacturers have constantly developed water-based varnish systems, among others due to the stricter requirements of the environmental law and the recognized weaknesses. Today, according to varnish manufacturers and literature, worthy water-based varnish systems are available for solvent-containing coating systems.
Due to the high significance set on the visual quality requirements by the Deutsche Werkstätten, the most important question in this regard is, whether high-quality water varnishes can meet these requirements. Therefore, the following examination is aimed at the determination of the applicability of water-based coating substances in terms of the visual criteria. At the same time, the possibilities of the water varnishes of the newest generation were presented to the decision makers during project planning of the orders with the help of an appropriate sensory analysis procedure.
For this purpose, a colorless water varnish and a water-soluble filler system were applied to a representative sample surface. In line with the sensory test procedure based on the DIN EN ISO 4120:2007 it was then compared to the common solvent-containing varnishes and coating structures respectively. An open-pore as well as a closed-pore coating structure with colorless 2K-water varnishes on a PUR basis was subject to the examination. Furthermore, a water-based 2K-filler system was examined for a colored coating structure with high gloss clear varnishing.

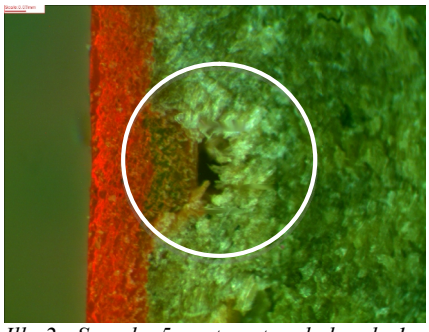
## 3. RESULTS AND DISCUSSION

***Surface Preparation***

Brushing out the veneered work pieces with a sisal cord brush, 8 times plaited, produced a pure pore structure without wood dust or mineral deposits and without visually changing the wood structure. As shown in Ill. 1&Ill. 2, the watered samples show better results. The following varnishing entailed a better flow of the varnish on the veneered work piece surface.



*Ill. 1: Sample 1, watered, brush 1; micr. imageCS (magnification 80x), fotonr. 1.8*



*Ill. 2: Sample 5, not watered, brush 1; micr. image CS (magnification 80x), fotonr. 5.7*

The complete wetting of the pores prevented the emergence of surface failures, such as air locks.[4] Direct savings of varnish can therefore not be calculated. However, the application of the brushingprocess in an existing project (surface processed: 2100 $m^2$) has affirmed these results and has therefore saved time and material-consuming rework. Future application of a brushing unit for the wide belt sanding machine has to be considered in relation to the arising costs of the manual brushing process. The wide scope of the geometry of the work piece needs to be considered as well.

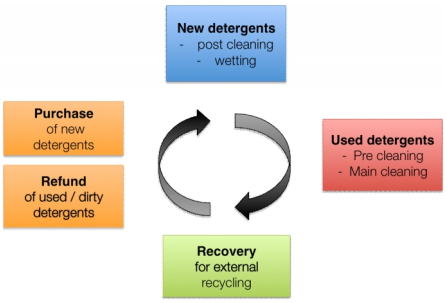
***Application Efficiency Factor***

The reduced (optimized) pressure settings for the three different pneumatic atomized spray guns (RP) and for the hydraulic atomized spreader with air assistance (AC) led to an increase of 11 and 7% respectively of the AEF for the surface coating. This entails a varnish saving rate of 31 and 20% respectively. The examination of the strip coating showed that not only the pressure settings but also the adjustment of the shape of the spray stream are decisive for an acceptable AEF.[5] The calculated varnish saving rate resulting from the higher AEF is directly transferable to the amount of solvents that was saved. Ill. 4shows the amount of varnish used per $m^2$, at a determined wet film thickness of 120 µm and a certain solids content of varnish – before and after the pressure settings were optimized. When the pneumatic application procedure (RP) was used, 37% of solvents were saved and 31% were saved when the air-assisted hydraulic application procedure was used for the primer.The implementation and adherence to the new pressure settings of the varnishing utensils is, among others, dependent on the work attitude of each single varnisher toward changes in the work process. [6] Simple control mechanisms or internal or external training courses can be suitable means ofsupporting the ideal settings and handling of the new varnishing utensils that are low in varnish dust.

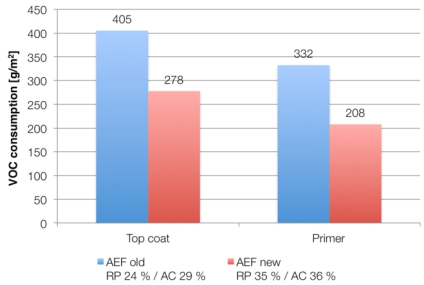
***Cleaning of Spray Guns and Utensils***

A new cleaning process, as shown in Ill. 3, which works with a defined amount of detergents and is aimed at the highest reclamation of detergents possible, was elaborated and established. The subsequent assessment of the amount of detergents used during a certain amount of workdays (WD) showed distinct differences in the amount of detergents used per detergent unit at several spray

stations. On the basis of the data a realistic required amount of detergents of 1 l/ WD and per spray station was determined. This amounts to a total quantity of 3 l/ WD for three spray stations.
Ill. 5shows the new total amount of detergents required versus the one of the year 2011.With reference to the total amount used of 2011, this reduction of 1,4 l of detergents per workday is equivalent to a saving of 32%. Additionally, the automatic washing machine for spray guns was excluded from the cleaning concept in consultation with the varnishers, because of its oversize for its cleaning purposes. A distillation plant for the reprocessing of the detergents had not been considered due to the expected lower cleaning efficiency of the recyclate so far. [7]
The implementation of the new cleaning process should take place in collaboration with the varnishers to encourage the comprehension and way of proceeding of the new cleaning process. Appropriate tools for self-control, for example a defined measuring cup per cleaning unit, and the correlating assessment of the amount used can support the implementation. After the completion of the year under review the total amount used should be contrasted with the recycledamount of detergents in order to reveal possible losses.




*Ill. 3:New circulatory cleaning process of the detergents*

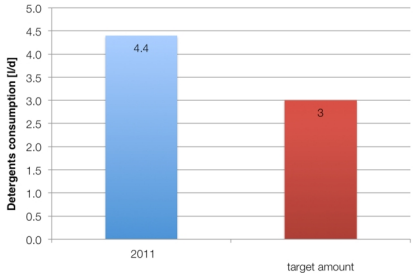



*Ill. 4: Savings of solvents [g/m$^2$] due to an AEF increase through optimized instrument adjustment at a layer thickness of 120 µm.*

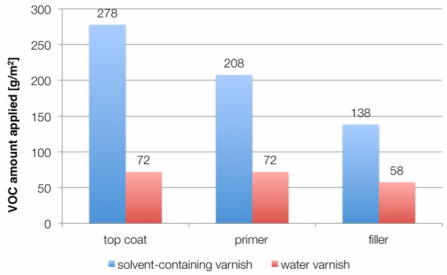
***Water-based Varnish Systems***

The sensory test based on DIN EN ISO 4120 of a water-based clear varnish system and a filling primer showed that the technology of water varnishes has improved considerably in the past few years. The examined water-based varnish systems based on 2K-PUR showed nearly the same visual features as the solvent-containing reference samples. The recognized differences were rather a result of procedural application flaws, which emphasize the necessary reorganization of the application procedure, drying process and varnisher for flawless varnishing when processing water varnishes. [8] Under this aspect the previous arguments against the application of water varnishes from a technological point of view are not justifiable any longer.
Another argument in favor of the application of water-based varnish systems is the high potential for savings of solvents used. Ill. 6compares the amount used of solvent-containing varnishes and water varnishes. The amount used of VOC refers to 1 m$^2$ of a coated surface at a wet film thickness of 120 µm, defined solids content and a defined application efficiency factor. The savings – based on the amount used [g/m$^2$] – of top coat (83%), primer (80%) and filler (70%) are significant and emphasize the high potential for savings of the possible application of water varnishes.[9]
The changeover to water-based varnish systems should be implemented with caution and strategy. The examination of different varnish systems regarding their processing features and mechanic-technological as well as visual and haptic characteristics are a fundamental part of such an implementation. Furthermore, intensive collaboration with the respective varnishers is desirable in order to learn the necessary information about preparation, application procedure and drying process.[10]Consultation by external experts or respective training courses should be considered as possible measures. When comparing the costs of water varnishes and solvent-containing varnishes, the focus should lie on the varnishing costs per coated surface [€/m$^2$] and not, as thus far,on the costs

of varnish [€/kg].[11]A profound strategy of implementation can prevent a prejudgment of water-based varnish systems as inadequate for the varnish application at the DW due to procedural flaws.




*Ill. 5: Previous total amount of detergents used per WD and the target amount due to the new cleaning process*




*Ill. 6: Comparison of amount used of VOC of solvent-containing and water varnishes at a defined layer thickness of 120 µm, AEF and solids content.*

## 4. CONCLUSION

Optimized processes in the application of varnish, the usage of low-solvent varnish systems and the application of efficient application procedures are the fundamental points for the elaboration of production integrated reduction measures. The sum of all measures examined allow the DEUTSCHE WERKSTÄTTEN to reduce their consumption of solvents and thereby meet the requirements of immissioncontrol laws in the near future without having to carry out effortful changes regarding their industrial manufacturing equipment.

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