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ASSESSMENT OF COMMONLY USED CLEANING METHODS ON THE ANATOMICAL STRUCTURE OF ARCHAEOLOGICAL WOOD

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Abstract

This study was conducted to diagnose and evaluate the effect of commonly used cleaning methods in Egypt on the anatomical structure of archaeological wood samples. Beech wood samples, which were taken from anonymous mashrabia, have been cleaned mechanically and chemically, then a scanning electron microscope (SEM) study was undertaken, to monitor any significant structural changes in wood samples due to cleaning processes. SEM data, however, show that cleaning procedures, both mechanical and chemical, affect the anatomical structure of wood, and do not achieve the best result. The main problem is that the effect of reagents cannot be easily removed from the wood structure. Ethyl alcohol proved to have the minimal effect on the wood structure in this study.

Keywords: *Archaeological wood; mechanical cleaning; chemical cleaning; SEM.*

Introduction

Cleaning archaeological wood with mechanical and chemical methods is the treatment procedure performed most frequently. Good cleaning can be achieved only through careful attention to details, in choosing the suitable tools and materials which influences the quality of the results. Cleaning involves the removal of surface dust, grime, accretions, stains and other alterations made to the artifact after collection. Cleaning is an irreversible process and should be approached with caution, as it can be damaging or can result in further alteration of the artifact [1].

Dirt and other surface deposits accumulated on archaeological wood can be removed mechanically by brushing with soft to hard brushes, scalpels [2], or by using abrasive blasting techniques [3]. Although mechanical cleaning should enable a degree of control over it, should avoid adding any substance that causes additional damage, like chemical cleaning, it has disadvantages too for several reasons: incorrect mechanical cleaning can lift or disturb fibers and cells, especially if the deposits adhere strongly to the wood surface. Moreover, the use of various tools in the mechanical cleaning can result in microscopic scratches on the surface of the wood [2].

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For conservation purposes, chemical cleaning is often applied, by using different reagents and solvents. In some cases the chosen concentrations are very low; in other cases the concentrations used may be too high and unsuitable [4]. Problems resulting from swelling and shrinkage of the wood may not be avoided when chemical cleaning is applied. Swelling of wood is encountered whenever a substance is added or removed from the cell wall and it was found that cellulose, which is the primary a wood polymer, is mainly responsible for the amount of swelling of wood [5-9].

Traditionally, solvents were often used for removing contaminates, by local application using brushing, spraying, immersing, or as vapors. The method of application is carefully chosen according to: (a) the nature of the artifact, (b) the type of dirt to be removed [1]. Solvents cause damage through swelling of cell walls; and they remove soluble components of plant tissue, especially extractives [1, 10]. Organic solvents are sometimes mixed with detergents or water to improve efficiency, which causes more damage [11].

El Hadidi & Darwish [4] studied the effect of acids and alkalis on the archaeological wood and concluded that their effect cannot be easily removed from the wood and that continuous washing with water for the removal of reagents may cause an increase in wood moisture content, which could be the source of future microbial decay. Acids and alkalis seriously affect the chemical composition of wood, and the choice of acids and alkalis should therefore be limited during the cleaning process of archaeological wood.

Therefore when dealing with valuable cultural heritage items, researchers have constraints in choosing the right solution for cleaning procedures, in order to obtain good results in removing the dirt and to produce no chemical or mechanical damage to the surface. Moreover, they should not to leave residues on the surface after the cleaning agent removal [12**].** Finally, this experiment was conducted to study and evaluate the effect of traditional mechanical and chemical procedures, commonly used in the cleaning of wood, on the anatomical structure archaeological wood.

Materials and Methods

The wood samples were taken from mashrabia of Ottoman era, that had been exposed to weathering effects and underwent previous repairs after it was covered with dirt, a thick layer of coating and adhesive residues. They were chosen for studying the effect of commonly used cleaning methods for archaeological wood in Egypt at the present time. The samples were from the mashrabia's wood turning, which was identified as a hardwood ***Fagus sylvatica*** **L.**

For mechanical cleaning we used brushes, wooden and metal scalpels.

We used Ethyl alcohol (95%), acetone, toluene, diluted acetic acid (1%), and ammonium hydroxide (1%).

All samples were studied before and after the cleaning processes. Small wood pieces (2×2×5 mm) were removed from the selected wood samples and then mounted on aluminum stubs with double-sided cellophane tape. After coating them with gold (Polaron sputter coater), the samples were examined by SEM (Jeol JXA-840A).

Results

SEM micrographs revealed the foreign resinous material that covered beech wood surfaces, mostly resulting from a previous restoration, mixed with dust (fig. 1a and b). After cleaning the beech wood with the mechanical method, by using brushes and scalpels, the results

showed that mechanical cleaning was insufficient to remove the coating material (fig. 2a). Moreover loose and eroded parts of cell walls were identified, especially in the middle lamellae region in cell corners, due to mechanical cleaning, which caused general weakness in the wood structure (fig. 2b). The cells were pulled apart, which may also be due to the tools used in the cleaning process (fig. 2c).

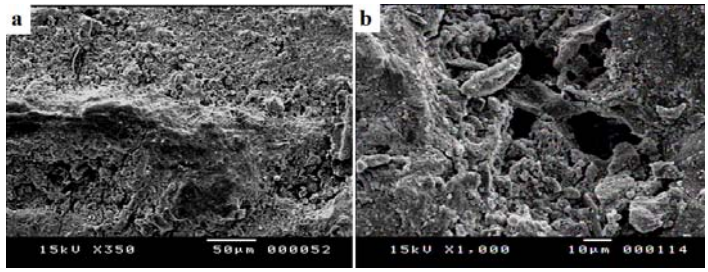

Fig. 1. SEM micrographs of transverse sections of weathered beech taken from wood turning of the Mashrabia: **a -** the surface covered irregularly with a coating material mixed with dust before cleaning processes (350X), **b** - the deposited coating material on the surface of the wood, which fills the wood cells more clearly (1000X).

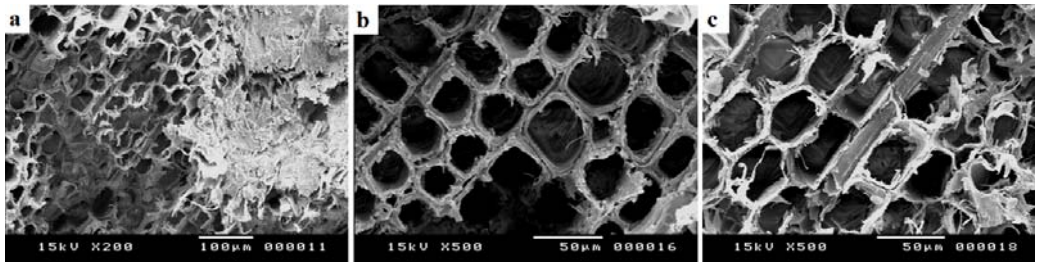

Fig. 2. SEM micrographs of transverse sections of weathered beech showing the surface after mechanical cleaning: **a -** mechanical cleaning removed parts of the resinous material which covered the surface (200X), **b -** loose and eroded parts of cell walls due to mechanical cleaning (500X), c- a weakened condition of the wood is seen and the cells were pulled apart, apparently due to the tools used in the cleaning process (500X).

Cleaning beech wood with ethyl alcohol (95%) achieved satisfying results (fig. 3a), but it caused separations between cell walls, which may occur due to shrinkage after evaporation the solvent (fig. 3b). Observation shows saturation of the cells with the resinous material (fig. 3c).

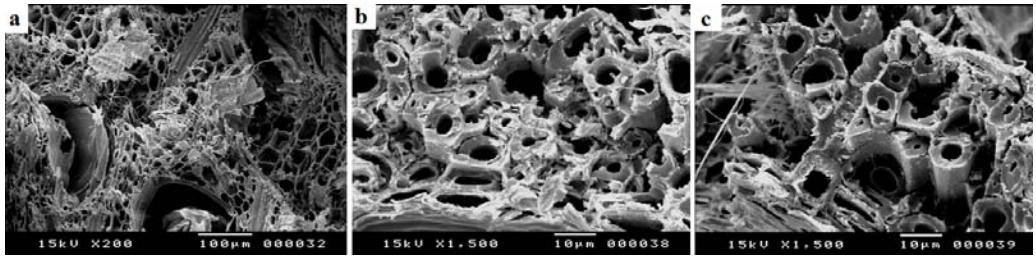

Fig. 3. Transversal sections of beech wood after chemical cleaning using ethyl alcohol (95%): **a -** the result of cleaning processes and the remnants of the coating material inside vessel cells, and on the surface of fiber and parenchyma cells (200X), b - Disintegration of the cell walls and separations between cell walls (1500X), c - cell walls saturated with the resinous material used in previous repair, also a separation between cell walls (1500X).

Wood sample cleaned with acetone showed that acetone is more effective in cleaning the surface of the wood, but it caused considerable deterioration (fig. 4a). Separations between cells and disintegration were evident, resulting in a loss of structural integrity (fig. 4b). Cell walls were eroded and disrupted causing distortion of wood tissue. Cracks extended within the cell walls, also some regions of the wood had cell walls that were severely degraded (fig. 4c). Moreover, loss and erosion of the middle lamellae region caused detachments within cells. General collapsing in wood structure was observed. The beech wood samples cleaned with toluene showed that toluene had a poor effect in cleaning (fig. 5a). Cracks and fissures resulted in the resinous material film deposited on the cell walls, due to mechanical pressure resulting from shrinkage, after toluene evaporation following the cleaning process (fig. 5b). Distortion of the cells and erosion extended through the cell walls were observed. Moreover, loss and erosion of the middle lamellae region caused detachments within cells resulting in a general collapse of wood structure (fig. 5c).

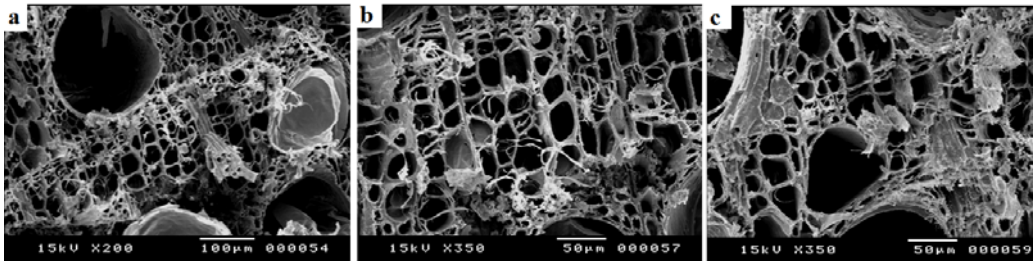

Fig. 4. Transversal sections of beech wood after chemical cleaning using acetone: a - the capacity of acetone significantly to clean the modern coating material in spite of the appearance of the remaining parts of this material within some vessel cells (200X), b - disintegration of the fiber cells and separations between them were observed. Cotton fibers used in cleaning process appear on the surface of cells (350X), c - serious effect of acetone on the wood surface which appears in distortion and disruption of cells. Also, some loss of integrity in cell walls was observed (350X).

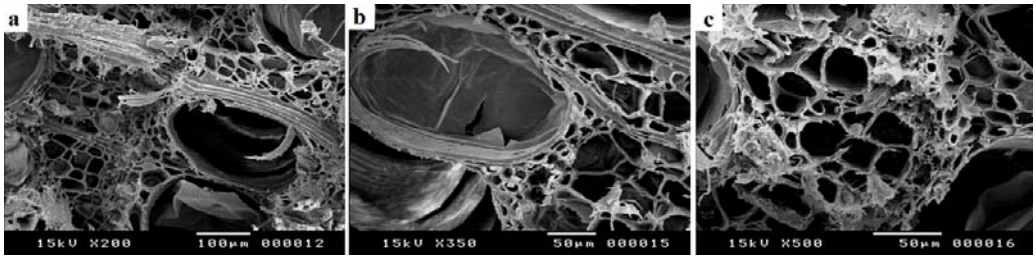

Fig. 5. SEM micrographs of transversal sections of beech wood after chemical cleaning using toluene: a - Effect of toluene in removing the modern coating material, beside that remnant of this material on the wood surface (200X), b - cracks and fissures in the resinous material film deposited on the cell walls due to mechanical pressure resulting from shrinkage after toluene evaporation (350X), c - compaction, distortion and erosion of the cells (500X).

The results from the wood samples cleaned with ammonium hydroxide (1%) indicate that ammonium hydroxide (1%) was less effective in removing the coating material, as the cells were still filled with the resinous material (Fig. 6a). Separation coating films from vessel cell walls is seen. We also observed erosion and loss in the middle lamellae region, which caused detachment within cells and the loss of some cells. Considerable deterioration with cells of

distorted sizes and shapes can be seen and some cells are eroded badly (Fig. 6b). Severe deformation and loss of cells coherence is present, due to eroded, collapsed and compressed cells (Fig. 6c). Transversal sections of wood samples cleaned with acetic acid (1%) displayed an area with cells that were not only collapsed and disrupted but also appeared fused together, although, acetic acid did not seem to be effective in removing the coating material (fig. 7a and b). Disruption of vessel cells and distortion of wood cells, which are still filled with the resinous material can be observed. Also, secondary walls in some cells are eroded.

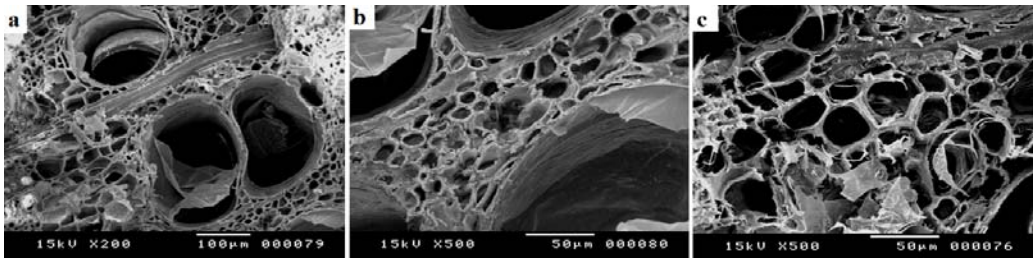

Fig. 6. SEM micrographs of transversal sections of beech wood after chemical cleaning using ammonium hydroxide (1%): a - Ammonium hydroxide (1%) was less effective in removing the coating material as the cells are still filled with the resinous material (200X), b - Considerable deterioration with cells of distorted sizes and shapes (500X), c - great degree of collapsed and compressed cells (500X).

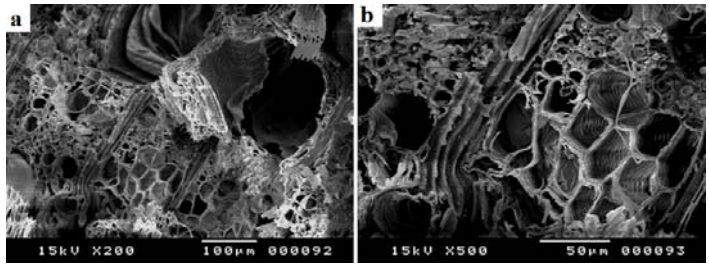

Fig. 7. SEM micrographs of transverse sections of beech wood after chemical cleaning using acetic acid (1%): a - acetic acid (1%) being not effective in removing the coating material whereas it cause a serious effect on wood structure. (200X), b - loss of structural integrity in the cells by the bending of cell walls and distorted cell shapes (500X).

Discussion

Many difficulties may arise when choosing a suitable method and material to clean archaeological wood. Mechanical cleaning proved to be insufficient, as layers of the remaining parts of coating material could be seen on the surface. Despite the fact that mechanical cleaning can be controlled, it led to severe deterioration, such as laceration of the cell walls in the wood surface, the disintegration of cell wall layers and loses in parts of the middle lamellae, due to the action of the tools used in cleaning; because the resinous material mixed with dust was very tight and adhered to the cells on the wood surface, removing and getting rid of it by using a scalpel led to a severe friction with the surface, resulting in a laceration of cell edges and the cell walls were disrupted and pulled apart.

The investigation of the samples cleaned chemically revealed that chemical cleaning adversely affects the anatomical structure of wood and causes pressure and stresses on the cells as a result of expansion and contraction caused by penetration of the solvent during the cleaning process and its evaporation once it is finished. The results proved that despite the damage recorded by SEM, it may be caused partially by the weathering process, but it is certain that the use of reagents in removing modern coating layers that accumulated on the wood surface increased the damage to the wood cells.

Comparing the results obtained from the archaeological samples that were cleaned with the selected reagents, showed that acetone is more effective in removing the resinous material than ethyl alcohol and toluene which achieved a satisfying result, whereas ammonium hydroxide (1%) and acetic acid (1%) were less effective in cleaning. Also, the cells with large diameters were easier to clean than the cells with a small diameter. Examination of the samples emphasizes that acetone had a serious effect on the wood structure; where it caused distortion and disintegration of cells resulting in a general weakening, but toluene caused stress and distortion within cells. Ethyl alcohol had a minimal effect, as it caused separation between cells due to shrinkage and contraction resulting from solvent evaporation. These results were consistent partially with results obtained by El Hadidi & Darwish [13], as they revealed that acetone and ethyl alcohol accelerate decomposition and oxidation of cellulose and lignin, while toluene caused a slight change compared to the other solvents. It was noted that ammonium hydroxide (1%) and acetic acid (1%) severely affected the wood structure; as they caused a bad erosion and loss of parts of the cells, disintegration of cell walls and a loss of structural integrity in the cells, which is consistent with the results achieved by El Hadidi & Darwish [4] on the effect of acids and alkalis on the chemical composition of archaeological wood. They mentioned that acids and alkalis had severe effects on the chemical composition of wood in general and especially on archaeological wood.

Practical applications

Solvents, acids, and alkalis, used in chemical cleaning, seriously affect the anatomical structure of wood, but ethyl alcohol had the least influence on the surface of archaeological wood in this study. It must be clear that the knowledge of the type and the chemical composition of coating material, which was used on the archaeological wood surface, in addition to its properties, lead to good results during cleaning, as it contributes in the selection of the best cleaning method to remove it and also reduces the amount of solvents used in the cleaning process, the length of time the wood is exposed to the solvent and the amount of mechanical action necessary to remove the foreign accumulation. It also increases the chances of a good cleaning.

Conclusion

Cleaning archaeological wood by using the commonly used cleaning methods in Egypt has been investigated by using a scanning electron microscope. The conclusions we reached in this research can be summarized as follows:

- Cleaning procedures, both mechanical and chemical, affect the anatomical structure of wood and do not achieve the best result.

- Mechanical cleaning should not reach the wood surface.
- Cleaning with traditional chemical cleaning results in considerable deterioration and serious changes in the anatomical structure of wood, which varies according to the reagent type.
- Ethyl alcohol had the minimal effect on the wood structure in this study.
- We must emphasize the importance of analyzing the surface layers we need to clean, to determine the best reagent and reduce its harmful effect on the wood structure.
- The choice for acids and alkalis should be our last resort during the cleaning process of archaeological wood

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