European Journal of Science and Theology, June 2009, Vol.5, No.2, 57-68

THE CONSERVATION OF ARCHAEOLOGICAL WOOD

Doina Maria Creangă*

University 'Ştefan cel Mare', Faculty of History and Geography, Universitatii street no.9, Suceava, Romania

(Received 19 January 2009, revised 25 March 2009)

Abstract

The work presents particularly complex problems of the conservation of the wood proceeding from diverse types of archaeological sites, the phenomena of degradation that appear and the main measures of prevention of the effects of the processes of heating and loss of humidity content from the wood, immediately after uncovering

Keywords: conservation, archaeological wood, site, impregnation

1. Introduction

A good conservation of archaeological wood is conditional on taking immediate measures, at the place of discovery, which concerns the intact maintenance of the object's state, depending on the environment from which they come. The immediate dehydration leads to the degradation of this material, which becomes fragile through drying. In addition, high-level humidity, correlated with the right temperature, brings about the intensification of biological activities.

The discovery of many wooden objects in dry environments shows that some are kept well in this state. The most organic materials were found in bogs. The essential condition for keeping them in the soil is their nature, the presence and mobility of water, the pH of the soil, the microclimatic stability or instability and the presence of salts.

A problem of maximum importance for the conservation of wooden archaeological objects concerns the optimal measures that must be taken even at the place of discovery. These measures are different, depending on the microclimatic conditions of the soil and the water content of the materials.

* e-mail: doinacreanga@yahoo.com, phone: +40 230-212138

2. Means of conserving archaeological wood

2.1. The conservation of archaeological wood proceeding from sites with water

Very many objects or fragments of them are dug up by archaeologists from deeper strata of the soil, which is strongly imbibed with water. A good means of initial conservation, at the place of discovery, is keeping these objects in a damp state. If these objects are dug up and left on the surface, even for a short period, they will lose water rapidly, due to the strength of the higroscopicity. This process of rapid loss of water brings about the disintegration is pulverisation of the material.

In the case of materials saturated with water, in order to avoid the loss of moisture, the following measures should be taken [1]:

- the rapid transfer into polythene bags, which contain water, added by impregnation of absorbent materials (textiles, filter paper and others) and a certain quantity of the soil in which they were discovered;
- the immediate sealing of these bags, with a hot source if possible, or by tying very tightly with a rope; a system of 'bag in bag' can also be used;
- the water to be used should be analysed from the point of view of pH value, concentration and types of salts contained therein. If they differ from those contained in the soil, important changes to the object can take place. It is recommended that running water is used and to avoid lake and basin water, which contains a very large quantity of microorganisms and salts. In order to avoid any change in the structure, the water should be filtered or deionised water should be used.

In order to avoid any errors the following measures should be taken:

- a separate sample of the added water in the bag in which the object is put;
- a sample from the polythene bag (this is necessary, because the bag can contain different soluble substances in water, which can contaminate the object: if such substances are identified, this should be noted in written documentation if found);
- a sample of the soil strata in which the discovery was made;
- the avoidance of adding fungicides, which can create ulterior difficulties in identifying the tannins; but if the temperature is considered to be too high there is also a danger of releasing microbiological activities, fungicides can be added with the condition of keeping a sample of this; the adding of the fungicide should be done, according to the research in this field, choosing only the range, which has been tested and accepted in conservation and restoration practice.

2.2. The conservation of archaeological wood proceeding from dry sites

Many times, wooden objects discovered in dry places are in a good enough state of conservation. The difficulty lies in the way in which they are handled and restored initially. From this point of view, it is peremptorily necessary that before taking these objects from the environment in which they were kept, a series of suitable measures to be taken.

These measures must keep them firstly in the state of extreme dryness, in which they were at the time of their discovery. Materials coming from dry sights have very low water content. If immediately after discovery these fragments are taken from their natural environment and are left in another environment, which has higher water content, the materials absorb a large quantity of humidity, until they reach a balance with their new ambient environment. In this case, due to their structure, also so fragile, combined with the beginning of microbiological activity, the result is the disintegration and complete loss of the material.

To avoid rapid humidification, the following measures must be taken:

- the laying of the objects or the fragments in polythene bags, equipped with perforations (in these bags, the material will be transferred to the laboratory; the perforations allow the achievement of some changes, between the content of the bag and the surrounding environment);
- in the laboratory, the object will be transferred into a dessecator or into special container, which closes very tightly with a lid, in which will be placed silica gel and calcium chloride in granule form (gradually, the means of the laboratory permit the bringing of the objects to their original structure and shape, enabling the avoidance of the loss of certain important fragments, in this way, the objects will be able to be studied, without the risk of their disintegration).

2.3. The loss of humidity content of archaeological wood

At the moment of their discovery, the loss of the humidity content of the object is the most harmful process which is unleashed. All organic materials have certain water content. Whether the percentage is small or even if it is said to be an object saturated in water, the sudden loss of this absorbent humidity is an extremely dangerous process.

This is, in fact, the most important process which gives a critical character to the moment of discovery. The fact that all the factors mentioned: temperature, humidity and incident radiation have the effect, individually and together, of eliminating water from organic objects, taken from archaeological digs, has to be specified.

The elimination of water from these materials has many other effects. The most important is the sudden dehydration of objects manufactured from natural, absorbent organic materials. The phenomenon has a direct effect, the degradation of the materials into a precarious state of conservation, as a result of the state of stable equilibrium with the environment in which they sat for a long period of time.

The loss of water from the structure of these materials, in uncontrolled conditions, determines the collapse of the internal structure of wooden objects. Just several hours after discovery, if adequate measures of preventative conservation are not taken, these objects lose 90% of their weight and 80% of their volume.

2.4. Organic materials, saturated with water

Wooden objects which have natural humidity content are flexible, can be handled without the risk of producing physical-mechanical degradation. A material which is saturated in water and whose structure has been seriously affected by ambient conditions, will not behave in the same way. Through losing the water content, the material will suffer an internal cell structure collapse, following from a loss of shape, cracks and splintering, which leads eventually to the loss of the object.

In the case of archaeological wood which was saturated in water and suffered structural losses, the loss of humidity content can be tantamount to the loss of the respective asset. For these objects, the only possibility of keeping its shape and to a certain extent its appearance, is the replacing of the water content with other substances. These treatments can't be performed in restoration laboratories.

2.5. Organic materials, not saturated in water

The maintenance of humidity is also necessary in the case of materials which are not saturated with water. If water is maintained in the structure of the materials, these could be handled provided that they are treated with great care. In the opposite case, the loss of water will lead to their drying. The consequence is their stiffening and crumbling at the smallest touch or mechanical tension.

The process of dehydration is not instantaneous. It has a certain kinetics, which depends on the evaporation rate. The lower the relative humidity and the higher the temperature, the more rapidly water evaporates, until it stabilises a new balance between relative environmental humidity and the humidity of the object.

2.6. The loss of water content. Phenomena of degradation

Amongst aggressive factors which act on archaeological wood, polluting agents or those of a microbiological nature are counted.

As far as polluting agents are concerned, it must be made clear that, in general, archaeological work sites are situated outside of heavily polluted zones and their incidence is a little lower. The reality is that, up until now, we have not the necessary means for their neutralisation. Pollution in a museum can be neutralised by an air-conditioning system, equipped with a special filter or can be reduced by sanitation measures. Under the conditions of a work site, found in an open field, this is almost impossible. After the introduction of objects into warehouses, the phenomena caused by polluting factors can create great difficulties to good conservation [2].

On archaeological work sites, even more dangerous for the discovered goods are spores of microorganisms. These settle on the surface of damp organic materials. In the event in which favourable temperature conditions also come together, this establishes massive, very dangerous attacks. Nevertheless, microbiological activities may act against the attacks even on the archaeological site.

2.7. Preventative measures for the effect of the processes of heating and loss of humidity content on the wood immediately after discovery

The developing effects in the processes of heating and the loss of humidity content of organic archaeological discoveries can be prevented.

The condition is to act immediately after discovery, through special measures which wish that the thermal equilibration of the wood to be made as slowly as possible and to maintain intact the humidity content of it. For this, the following measures must be taken:

- the transportation of the object as quickly as possible to the equipped precincts for this purpose, with a view to slowly stabilising the humidity content, in relation to the ultraviolet radiation of the respective environment;
- in case that the discovery of an object necessitates a longer time, because the escape operation is made centimetre by centimetre, the free area must be covered immediately. In case of objects manufactured from materials which have a high humidity content, which must be kept, on the uncovered part a damp cloth must be placed, impregnated with an antifungal and antibacterial substances. The damp cloth ensures the maintenance of the humidity. On the other hand, in conditions of rapid changes of the object's temperature, e.g. an increase of the values, in order to impede the commencement of the biological attacks, an antifungal substance is added. It is very important for this substance not be volatile, because the volatility decrease the efficiency of the substance;
- to perform, in the shortest time, the operations which the archaeologist considers indispensable to the object in the context of discovery;
- the assembly of protective tarpaulins at the place of intervention in order to eliminate incident radiation. The tarpaulin doesn't only eliminate the incident radiation but also the effects of other factors;
- the immediate determination of whether an object has a humidity content which must be kept intact and the rapid packing – with a fungistatic supplement, in watertight containers or bags and urgent dispatch to the

restoration laboratories of organic materials. The packing must be kept as well closed as possible.

Until transported to the restoration laboratory, the packed object must be kept in a specially arranged place, with as low a temperature as possible. It would be normal that the site has the possibility to dispatch, urgently, to the profile laboratory, all objects made from fragile, organic materials and whose state solicits immediate intervention.

From then, it is recommended that the unit which made the discovery and which doesn't possess a profile laboratory (or has laboratories specialised in inorganic materials, which cannot resolve difficult problems created by organic materials), establish in time, relationships with laboratories specialised in organic materials.

For the discovered objects, the achievement of a state of equilibrium with the relative environmental humidity, must be made as slowly as possible, in order to prevent the damaging effects created by the eruption of the salts [3].

The fate of archaeological discoveries of organic materials involves a very large responsibility. That's why, whenever archaeological prospecting is started, all conditions must be secured in order to save discoveries of this type. In the opposite case, the absence of suitable, preventative means of conservation can affect, even compromise, the state of the discoveries.

Since the problems of the instability of archaeological materials are very complex, whenever such vestiges are discovered it is indicated to have a professional restorer present on the site. He can assist at all stages of the discovery, preventing in this way the appearance of further degradation. However, all treatments are made in the restoration laboratory, which has the necessary conditions for optimum intervention.

2.8. The depositing at the site of archaeological wood from digs

After the discovery and extraction of the discovered materials, the next phase is the depositing of the objects discovered on the site. The depositing mode must be considered very seriously because the conservation state of the object depends on these conditions.

From the moment of the discovery, a critical period starts for the archaeological wood, which stops only after its stabilisation has been secured by treatments done in profiled laboratories. The distance between the two moments, respectively discovery – stabilisation, must be as short as possible. The duration of keeping the object at the archaeological site must be as short as possible. The immediate transportation of discovered materials to the profile laboratory is necessary.

Maintaining for a long duration in site conditions, the wood would suffer a rapid process of degradation. For the whole period of being held at the archaeological site, the measures of conservation secured in this interval are crucial.

In general, the high humidity content of wood always represents a risk factor. The given situation of the archaeological discoveries is another. The elimination of water has a direct result on the irreversible degradation of the respective object. For many organic materials, coming form archaeological sites, the intact maintenance of the humidity content represents the only rescue possibility.

In spite of the fact that water has negative effects, i.e. it favours the development of microorganisms and activates chemical processes of degradation, the temporary maintenance of water in the structure is indispensable. In the case of archaeological wooden pieces saturated with water, which have compromised interior resistance, the maintenance of humidity content is indispensable for keeping the shape and interior resistance from the moment of discovery.

In the case of these materials, the rescue can be made by the replacement of the water in the structure with a substance which takes the resistance role played by the water until the discovery time. If such a material retains the water it can be considered stabilised, so that it can await a conservation treatment [4].

For wood saturated in water, there are many other possibilities of maintaining the water content. Putting in a bag to which has been added a bioacid, arrangement of a water reservoir or burying the objects in a sandy soil, in which the humidity can be maintained, are frequently used methods, until the opportunity to transport them to the laboratory arises.

For any of the applied procedures, the principle remains the same: the maintenance of the humidity content, the prevention of the appearance of microbiological attacks, after which follow the laboratory treatments which can be made, for objects saturated in water, the replacement of water with polyethylene glycol in special installations, process which is particularly long standing and complex.

There are archaeological discoveries with wooden objects found in a good state of conservation. In this situation, their only problem consists in the fact that in the hours immediately following the discoveries, after the separation from the dust and impurities, they must be transported to a space with a lower temperature, in order to enter into equilibrium with relative ambient humidity. Subsequently these will be kept in the precincts with a microclimate as stable as possible and will be warmed up accordingly.

3. Means of stabilising archaeological wood

Conservation works intend to stop the wood contraction due to the elimination of the water by the drying. This allows the maintenance of the wood at maximum size and adequate state of saturation. Due to this fact the internal tensions are annihilated and the wood keeps both form and dimensions, without being destroyed or without suffering deformation and degradation, although finally it is dry. This process is called the dimensional stabilisation of damp wood.

There are three main ways to deal with the problem of dimensional stabilisation of wood containing exceeding humidity, to prevent the destruction of it at the moment that the water is eliminated.

The first way, and the most often used, involves that category of methods through which gaps in the interior of the wood are filled with solid materials, which resist to the deformation and which are capable of replacing the water in the wood.

The second way consists of eliminating the water from the wood by using an intermediary liquid, which must be preferably non-polar and which has a superficially low tension. When the replacement liquid is eliminated, in its turn, a porous structure results without dimensional changes, which accompany the direct evaporation of the water, thus without causing the collapse.

The third way uses the methods of freezing the water from the wood and the sublimation of it in vacuum (drying through freezing).

Within the framework of these ways, until now, over 25 distinct and differentiated methods, depending on the wooden substances, degradation and the dimensions of the wood and the used substances and technologies, are known.

Making a systematization of these methods, in accordance with the best criteria (i.e. the used substances) we can group them in methods which are using: salts (borax, alum, sodium chloride, etc.); sugars; natural resins (camphor, Canadian balm, dammar, sandarac, etc.); synthetic resins (vinyl chloride, methyl methacrylate, acrylic nitrate, etc.); wax and paraffin; polyethylene glycols (in over 10 variants).

The choice of the most adequate methods depends on a multitude of factors and circumstances. Thus, the reactions of the used substances to humidity, the structure and the extent of the degradation of the wood, the microclimatic conditions of the exposition or depositing of the wood, the aesthetic exigencies and not lastly, the economic viability play an important role in the decisive act.

The conservation technologies applied on a wide scale in the world have at the base, in principle, the use of polyethylene glycols as substances of dimensional stabilisation for the wood with an excess of humidity. Amongst other methods, the majority are less suitable in practice, as their use and the technologies necessitate the use of expensive apparatus or lead to the worsening of other important properties for wood, before all, of the mechanical resistance.

Polyethylene glycols (PEG) are polymers of ethylene – glycols in which the extent of polymerisation for the types that present interest in practice are from 3 to 135, corresponding to an average molecular weights of 200 to 6000.

These are non-odorous, non-toxic, hygroscopic, colourless products in a fluid state or with a whitish aspect in a solid state, not very volatile, resistant to many alkaline substances, acids, salts, practically neutral from a chemical point of view.

Their main feature, which makes them useful in the conservation of wood with excess humidity, is the solubility in water, an advantageous fact, water being the cheapest solvent. PEG can also be easily washed from a material impregnated, according to the principle of reversibility in restoration. From here results that the wood treated with PEG, without being protected with a pellicularisation, is not suitable for use in rooms with very high air humidity.

In general, the data regarding the dimensional stabilisation of wood concern its volume. By absorbing PEG into the walls of the cells, the wood is maintained in a state of ‘quasi-inflation’. The dimensional stabilisation by impregnation with PEG is dependent on the following factors: molecular mass (weight) of the type of PEG, the solubility of the polymer in water at the prescribed temperatures of impregnation and drying, concentration and viscosity of the solution of impregnation; the initial humidity of the wood; macro and microscopic structure of the wood and the extent of its degradation; the length of impregnation; temperature and drying rate of the treated wood; the working technique.

The absorption of PEG by different wooden substances linearly increases with the concentration of the impregnation solution, leading to the dimensional stabilisation varying between 87% and 96%. The initial humidity and the impregnation time of the wood are exceptionally important factors, on which depend the absorption of the PEG and the dimensional stabilisation of the wood. The diffusion of PEG into the walls of the cells also continues during the drying of the impregnated wood. In order to reach optimum values of dimensional stabilisation it is necessary that the drying process to be carried out at a very slow rate.

It is important to highlight the fact that the impregnation with PEG doesn’t emphasise the disadvantageous changes of the wood concerning: mechanical resistance, heat conduction, friction coefficient and the attack of biological agents.

Such an impregnation method was used in the case of archaeological wood coming from the *Church of Saint George (Mirauți) – Suceava*, a wooden coffin and several wooden fragments with circular arches shape – called *romanats* – used by the craftsmen to reach the bolts right in the centre of the tomb [5].

The coffin had the form of a prism, having at the base a trapezium. The external dimensions of the coffin were: length = 1.92 m, breadth west = 0.88 m, breadth east = 0.8 m, height = 0.39 m.

The coffin was worked from hard wood (oak) from planed long planks, with a thickness of 4.5 cm. In order to close the component parts, wooden nails of about 5 cm in length with a sharpened end, of the same substance, were used. The lid was fixed to the body of the coffin by means of eight iron clamps.

The lid of the coffin was formed from two planks; the western lid, from the head, with a trapezoidal shape was composed of a single piece, whilst the eastern part, from the feet, also trapezoidal, was achieved from two pieces. The bottom of the coffin, also trapezoidal, was made from two planks, while the lateral parts where formed from a single plank. Under the bottom of the coffin, in the eastern parts, two wooden poles were found, from the same substance as the coffin, having a dual role: support for the coffin, which was not in direct contact with ceramic slates of the tomb, and to fasten to the two planks which form the bottom of the coffin.

At the moment of the discovery, the lateral parts of the coffin were found fallen inwards, over the lid, while the bottom of the coffin was decayed in the median zone (Figure 1a).

At the beginning were removed the deposits from the dirt, stone and bricks from the surface of the coffin, using soft brushes, trying then to lift the pieces of the lid and put them on cardboard, wrapped in polythene, in order to keep the best microclimatic conditions possible from the interior of the tomb (Figures 1b and 1c).

Between the bottom of the coffin and the brick roof an iron sheet was introduced. The bottom of the coffin was taken out, together with textile fragments from the space of the tomb, was placed on a plank support and with the help of some ropes, was brought to floor level.

In order to avoid sudden changes of the physical-mechanical and chemical indices of the materials, due to the new microclimate conditions, as well as the possibility of contamination of the pieces of vestments with germs from the atmosphere, the bottom of the coffin together with the pieces of vestments were covered with filter paper and cotton wool soaked in formaldehyde and distilled water. Everything was wrapped in polythene and fixed by perpendicular binding, taking measures to prevent the impacts during the transportation to the restoration laboratory in Suceava. The archaeological wood was brought into the laboratory in the form of 11 packages and it was passed to the unbinding of the archaeological complex layer by layer.

The archaeological wood was deposited in the damp treatment room by the specialists from the wood workshop of the restoration laboratory, it was sprinkled with thymol solution 3% in absolute ethyl alcohol and distilled water, covered with a thin sheet of polythene in order to avoid the dehydration of the wood, until its immersion in PEG solution in PVC vats.

After this, the fragments of wood were cleaned with soft brushes from the dirt deposits and other impurities, were putted in two PVC vats containing a solution of PEG 1000, beginning with a concentration of 10% in water. The treatment operation with PEG of the archaeological wood from the Mirăuți complex started with a small concentration of 10% because the diffusion occurs slowly.

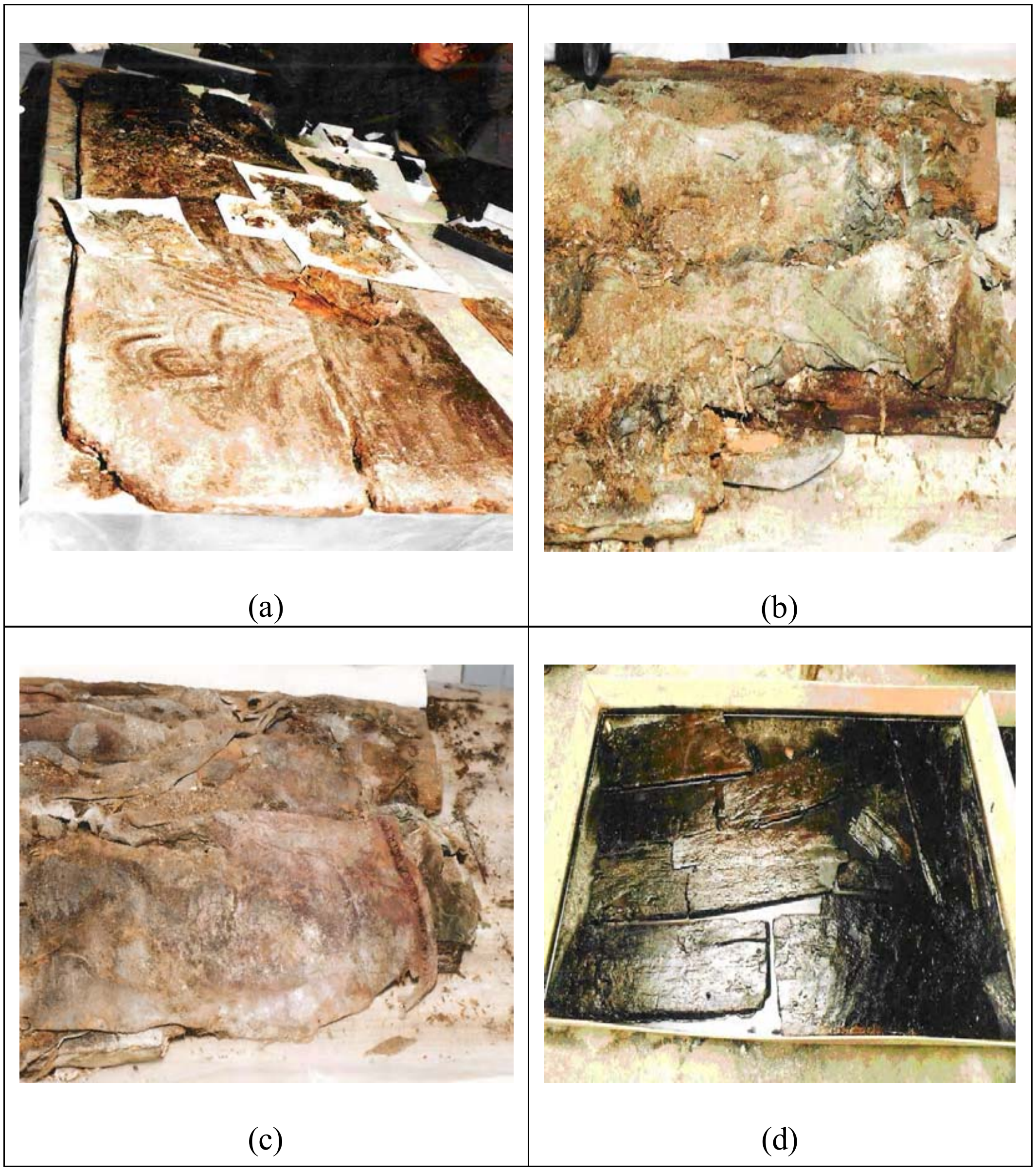

Figure 1. Aspects: (a) at the removal operation, (b) and (c) during the removal operation, (d) during the impregnation operation.

The increase of the PEG concentration was made gradually, over weeks, even months. The use of high concentrations of PEG, or of too short periods between the subsequent different concentrations, can lead to negative results. There is the danger that the water will be taken from the wood more quickly than PEG molecules penetrate into the fine structure of the wood.

The concentration of the PEG solution was increased from 10 by 10 up to 50% at intervals of two months. After impregnation, the wooden fragments were taken out of the vats and left to dry slowly at room temperature (Figure 1d).

Bearing in mind the very advanced level of degradation of the wood, the fragmentation of this and its fragility, the conservation was done by impregnation with Palaroid B 72 and treatment with PEG solution (polyethylglycol), in order to give back its shape.

After the removal from the bath with consolidation solution, the fragments were left in an open, well-aired space until the evaporation of the surplus of toluene.

4. Conclusions

When referring to the wooden objects revealed in an archaeological research, one must consider the importance and complexity of preventive conservation. The efficiency of the ulterior actions of restoration (stabilization and consolidation) highly depends on the conservation promptitude in the archaeological site.

References

[1] S. Ştirban, *Conservarea preventivă a obiectelor arheologice pe suport organic*, Aeternitas, Alba Iulia, 2002, 43.
[2] N. Melniciuc Puica and E. Ardelean, European Journal of Science and Theology, **4(2)** (2008) 51.
[3] A. Moldoveanu, *Conservarea preventiva a bunurilor culturale mobile*, Centrul de perfecționare a personalului din cultura şi artă, Bucuresti, 1998, 124.
[4] N. Melniciuc-Puică, *Materiale pentru realizarea, conservarea şi restaurarea icoanelor şi frescelor*, Tehnopress, Iaşi, 2001, 145.
[5] C.D. Neamțu and V. Ioniță, *Conservarea lemnului arheologic provenit din săpătura Mirăuți*, in *Restaurare 2000*, Venus, Iaşi, 2000, 232.