Measurement of the homogeneity of the relative humidity within the passive microclimate chambers used for preservation of the archaeological artefacts

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Abstract. The archaeological artefacts storage is possible in passive microclimate chambers, where relative humidity can be maintained using the moisture stabilizer. The aim of the paper is to check the homogeneity of the relative humidity in dependence on the distance from the moisture stabilizer in the horizontal and vertical situation of the chamber and to check the impact of the outside temperature to the conditions inside the microclimate chamber. We placed a plexiglass tube into the large climatic chamber. In the tube we evenly distributed four measuring probes that measured temperature and relative humidity. The measurements were carried out at 10 °C, 23 °C and 40 °C temperature and in three different tube positions: vertically (silica gel at the bottom of the tube), vertically (silica gel at the top of the tube), vertically (silica gel at the top of the tube) and horizontally.

1. Introduction

Conservation science is a general, by necessity an imprecise term that describes the work of scientists conducting research on works of art and their state of physical preservation. By common definition, work in this field falls into two major, extensively interacting areas: technical art history or archaeometry on the one hand and science of preservation on the other. Researchers in this applied science may come from very different backgrounds, transferring technologies into the field, or acting as interpreters of technical results. The second area is science of preservation, encompasses the study of degradation or deterioration processes of artefacts, as well as the development of strategies, technologies and materials for the conservation of cultural heritage. It includes diagnostic investigations, as well as the evaluation and development of conservation treatments. Part of this is the so-called preventive conservation, which tries to analyze and to minimize the environmental impact on works of art using various kinds of protection [1].

The archaeological artefacts storage is a very interesting research topic, with multidisciplinary background (history, chemistry, physics, technology…), which is still quite unexplored. It is typically recommended that the artefact is kept on similar or same conditions under which it has been for centuries. Most of these conditions are determined empirically and thus doesn’t have proper metrological traceability. Relative humidity fluctuates and materials adjust to new conditions. During repeated cycles of relative humidity, stress accumulates in objects and may endanger their structural integrity. Especially for significant works, best practice for maintenance requires preventive conservation measures to be taken prior to fracture, rather than remedial intervention after irreversible damage has occurred [2]. Typically extreme temperatures as well as changes of temperature are not significantly influencing artefacts. On the other hand, real examples of incorrect relative humidity in museums fall into one of four categories: damp, above or below a critical humidity, any humidity over 0%, and humidity fluctuations. Damp causes mould and rapid corrosion. Numerically, "damp" begins at 75% rh, but more important is the recognition that danger grows rapidly for every step beyond this point. Relative humidities above or below a critical relative humidity of 50 % rh affects minerals that hydrate, dehydrate, or deliquesce at a particular relative humidity. Besides natural history collections, this applies to contaminated metal objects (particularly marine or archaeological artifacts) and to some...
types of glass. Fluctuations in relative humidity are incorrect for artifacts that contain restrained moisture-sensitive layers. Certain artifacts, especially those that have recently been conserved, may also be very sensitive or vulnerable to relative humidity fluctuations and may require special protection. The acceptable fluctuation is defined as ±20 % rh around 50 % rh in 24 hours [3]. Among the most famous examples of archeological artefacts found in the vicinity of Slovenia are the Apoxyomenos from Lošinj, Croatia and the oldest wooden wheel in the world, 5200 years old, found near Vrhnika, Slovenia belongs to the very top of the world heritage. Parts of the Apoxyomenos and the oldest wooden wheel are preserved within passive microclimate chambers.

A 192 cm high classical bronze statue of a young champion athlete, named The Croatian Apoxyomenos (Figure 1), was found in 1997 by a Belgian tourist, René Wouters, at a depth of 45 m in the waters of the Northern Adriatic, between the island of Lošinj and the islet of Vele Orjule (14°33’ E and 44°30’ N). The statue lay caught between two rocks, wedged by the head and feet, and was thus prevented from rolling off further into the depths. Apoxyomenos was raised from the sea in 1999. Preserved in its entirety, even with the very rarely extant bronze plinth, the statue was also in very good condition, due mainly to the thick, protective layer of marine incrustation composed of the limey shells of marine organisms, [4]. After the Croatian Apoxyomenos was raised from the sea in 1999, it was extensively restored. It was not publicly displayed until 2006. It is the most complete and best preserved among eight known Apoxyomenos statues. The statue was covered with marine sediments and organisms. In the interior of the statue, various organic substances were found: pieces of wood, salts, fruits, seeds, insects ... To avoid rusting, crushing or decaying artifacts, restaurateurs try to determine the optimum conditions in which they could be stored for further years.

Figure 1: The Croatian Apoxyomenos, [4]  Figure 2: Wooden wheel, Vrhnika, Slovenia, [5]

A prehistoric wooden wheel with an axle discovered in 2002 at the pile-dwelling settlement Stare gmajne at the Ljubljansko barje, Slovenia. Analyses indicate that it was a technologically advanced product, manufactured by a prehistoric wheelwright. Considering its radiocarbon dating and the age of the settlement, where it was found, the wheel is c. 5150 years old. The prehistoric wheel from Stare gmajne was made as a disc with a rectangular central opening for the hub. The disc was made of two planks joined (tongue-and-groove joint) with four battens. Planks are made of ash Fraxinus excelsior with wide annual rings, of trunk of over 40 cm in diameter. Consideration of shrinkage and swelling of wood is very important, because the wheels are exposed to moisture (rain, wet ground) and drying, which is intense when exposed to hot sun [5]. This wheel is also kept under special microclimate conditions.

2. Design of the measurement system and measurement protocol

The measurement system consisted of the large volume climatic chamber, used to simulate realistic environmental changes that can occur in churches where some of these artefacts are stored, the passive microclimate chamber in form of the tube made out of plexiglass in which archaeological artefact is stored together with the moisture stabilizer and combined temperature/humidity measuring instrument with 5 channels.

The large climatic chamber had volume of 10 m³. The temperature range was from 0 °C to 50 °C. The length of plexiglass tube was 2000 mm, diameter was 170 mm. On the one side of the tube we have put the 200 g of PROsorb moisture stabilizer. Supplied as a complete unit, the prosorb cassettes require no additional containers or trays. Pre-filled with PROsorb beads, the cassettes are constructed from a sturdy polypropylene case with vapour permeable non-woven polyester panels. The cassettes have been preconditioned to 50 % rh. The enclosed PROsorb beads will absorb and desorb water vapour, as
appropriate, to stabilise the humidity [6]. The instrument used for the measurement was Ahlborn ALMEMO 2690 in combination with 5 combined probes for temperature and humidity measurement (Figure 3). The probes were calibrated at 10 °C, 23 °C and 40 °C, in the range from 10 % rh to 95 % rh. The expanded uncertainty of temperature measurements of the probes was 0.2 °C and of relative humidity measurements was 1.3 % rh. Four probes where evenly distributed inside the tube, while fifth probe was located outside of the tube – measuring conditions of the large climatic chamber. When installing the measurement system, we had to pay special attention to sealing. We had to ensure that the movement of air occurs in the tube and that the outside air from the chamber does not enter the tube. That’s why we used a silicone seal, sealant, glands, screws and flanges. At temperatures of climatic chamber of 10 °C, 23 °C and 40 °C, the temperature and humidity distribution in the tube was measured. These are typical minimum and maximum values that can occur inside non air-conditioned rooms, such as churches, over the calendar year. The measurements were carried out when the tube was in a vertical position and the silica gel was at the bottom of the tube, when the tube was in a vertical position and the silica gel was at the top of the tube and when the tube was in a horizontal position, Figure 4. We were interested in how fast the humidity is homogenized over the entire volume, and the differences when the humidity expands upwards or downwards when changing the ambient temperature. We also monitored transient phenomena when changing the ambient temperature. The measurements were performed over at least 20 hours at each temperature and each position.

3. Measurement results and analysis

The measurements were performed from November 2017 to January 2018. Typically measurements were performed over the weekend. In order to estimate influence of the larger quantities of PROsorb, one series of measurement was repeated with 400 g of PROsorb. In the Figure 5 we can see the extreme transition of outside temperature, from 40 °C to 10 °C (left y axis). At the beginning the relative humidity inside the tube has risen to 90 % rh (right y axis), but in two hours the inside conditions were within suggested limits 50%±20 % rh, [3]. In all figures, humidity measurements are presented in different nuances of blue color and on right y axis.

Figure 3: the measuring instrument

Figure 4: The tube in horizontal and vertical position

Figure 5: Transition from 40 °C to 10 °C
The one probe (dark blue on all figures), which was outside, was following temperature change appropriately, while it didn’t stabilize to 50 % rh. This confirms that sealing between the outside and inside of the plexiglass tube was made in a correct way. It has to be emphasized that such extreme change of outside temperature from 40 °C to 10 °C in less than an hour can be experienced only in experimental laboratory conditions.

In the Figure 6 the tube was in vertical position and PROsorb was on the bottom of the tube. At the beginning of the transition, we can see similar behaviour as on figure 5. We can see that relative humidity is very homogeneous inside the tube. The maximum difference between 4 sensors along the tube is less than 2 % rh. In all cases of the outside temperature change, in two hours the inside conditions were within suggested limits 50%±20 % rh, [3].

Even in case when the tube was put in horizontal position and the natural movement of humidity was worse, the conditions inside the tube where within suggested limits 50%±20 % rh, [3]. However, as expected, the homogeneity inside the horizontally placed tube was more than 4 % rh due to natural movement of humidity. We could improve this homogeneity if we place the moisture stabilizer along the tube and not only on the one side.

Figure 6: Vertical position – PROsorb on the bottom Figure 7: Horizontal position

4. Discussion
On the basis of the measurements, it can be concluded that a total stabilization of relative humidity within the tube takes about 20 hours after the rapid change of outside temperature. On the other hand, after two hours of extreme change of the outside temperature, the relative humidity in the tube stabilized below 70% rh, which is an acceptable limit for majority of archaeological artworks. The increased amount of moisture stabilizer did not have a significant impact on the response rate in the microclimatic chamber. The position of the moisture stabilizer in the vertical layout of the tube is not significant, but in the horizontal layout it needs to be divided into several places along the tube.

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