INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE

ISSN: 2067-533X Volume 8, Issue 1, January-March 2017: 67-80 www.ijcs.uaic.ro

NEW INSIGHTS INTO THE HEART OF VOLTAIRE USING A MULTIDISCIPLINARY APPROACH

Nathalie BUISSON[1*], Caroline LAFFONT[1], Amandine PEQUIGNOT[2], Cécile BADOUAL[3], Patrick FAULCON[4], Christophe NICH[5]

[1] Bibliothèque Nationale de France (BnF), Département de la conservation, laboratoire du site Richelieu, 5 rue Vivienne, 75002 Paris, France
[2] Muséum national d'Histoire naturelle, UMR 208 Paloc Patrimoines Locaux (IRD/MNHN), 36 rue Geoffroy Saint Hilaire, 75005 Paris, France
[3] Service d'Anatomie et de Cytologie Pathologique, INSERM U970 PARCC Equipe 10, Hôpital Européen Georges Pompidou – Assistance Publique – Hôpitaux de Paris – Université Paris Descartes, 20-40 rue Leblanc, 75015 Paris, France
[4] Service de Chirurgie Oto-Rhino-Laryngologique, Hôpital Européen Georges Pompidou - Assistance Publique - Hôpitaux de Paris - Université Paris Descartes, 20-40 rue Leblanc, 75015 Paris, France
[5] Service de Chirurgie Orthopédique et Traumatologique, Hôpital Européen Georges Pompidou - Assistance Publique - Hôpitaux de Paris - Université Paris Descartes, 20-40 rue Leblanc, 75015 Paris, France

Abstract

A rare occasion to investigate the conservation mode of the heart of the philosopher Voltaire (1694–1778) presented itself following an incident with his statue at the National Library of France which enclosed the organ. A multidisciplinary study was carried out to propose and implement an improved reconditioning method for the organ. The study generated a better knowledge of the fabrication technique of funeral metallic boxes as well as a better understanding of the degradation process of both the organ and the box. The heart and its conditioning, as well as the volatile products (VOCs) released by the heart were analysed with nondestructive methods. X-ray fluorescence spectroscopy (XRF) and scanning electron microscopy associated with X-ray microanalysis (SEM-EDX) were used for the identification of the metal, the preparation and the gilding of the metal box. The heart-shaped metal box is made of lead with tin welds. The box received a double layer white lead preparation. The binding of the preparation is probably of proteinic nature. Gold leaf had been deposited on a gilding bole made of a mixture of red ochre and minium, enhancing the preciousness of this particular artefact. Identification of VOCs released from the heart done by SPME fibres followed by gas chromatography-mass spectrometry (GC-MS) analysis confirmed the origin of the strong smell, essentially acetic acid. From the inside of the heart-shaped metal box, emission of VOCs suggest that the organ may have been embalmed in a liquid containing alcohol (spirit of wine), resins, natural extracts or essences from cedar or lavender. Histological analysis of tissue samples showed the presence of striated muscle fibres. These results helped to determine the optimal reconditioning of the heart. It has been decided to keep the organ inside its metal box in a stabilized environment with static anoxia, in order to preserve the heart for future generations while protecting the tissues against oxygen degradation for further investigations.

Keywords: *Heart of Voltaire; Gilding; Metal analysis; SEM-EDX; XRF; VOCs; CT scanner; Histology*

Introduction

French philosopher François-Marie Arouet, known as Voltaire, died in Paris on the 30th of May 1778, at the age of eighty-four years, at the mansion of his friend, the Marquis de Villette. The apothecary Mitouard proceeded to carry out the autopsy and embalmment of the

[*] Corresponding author: nathalie.buisson@bnf.fr

body. The autopsy report mentions that the heart and brain were removed in order to be conserved. Interestingly, it specifies that the brain was "very large" and that the heart was "very small". It also mentions that the bladder looked like bacon and was in a state of decomposition [1]. Modern medicine has diagnosed that Voltaire suffered from prostate cancer [2].

After the autopsy, on the order of the Marquis de Villette, the heart was placed in a gilded heart-shaped metal box filled with a preparation aimed at conserving the organ [1]. The box bore the following inscription: 'Le Coeur de Voltaire, mort à Paris, Le XXX. May MDCCLXXVIII'. The heart was brought to Ferney's castle, near the Swiss border, where it was exhibited in a room called 'chambre du Coeur de Voltaire' until the French Revolution [3].

When the Marquis de Villette died in July 1793, his son, Voltaire Villette, inherited the heart. At Voltaire Villette's own death in 1859, none of its heirs wished to keep the heart. The family's notary, Léon Duval, wrote to Emperor Napoléon III to donate the heart of Voltaire to the French State. The heart would then follow the same path as the philosopher's body, transferred to the Pantheon in Paris in accordance with the law of March 30th, 1791 [4].

Napoleon III duly accepted the donation and requested to place the heart at the Imperial Library. Victor Duruy, secretary of the state for education, received the organ on December 16th, 1864 [1]. The heart was temporarily placed in the Coins, Medals and Antiques Department, while the plan [5] was to later install it on the first floor of the rotunda, together with the plaster model of Voltaire's statue made by Jean-Antoine Houdon (1741–1828), medals struck in his honour, his written correspondence, and his printed works. This project was partially achieved: the heart and the statue were reunited, the former placed in a wooden case, inside the wooden base of the statue with the following inscription: 'Coeur de Voltaire remis à la Bibliothèque impériale par les héritiers du marquis de Villette' (Fig.1). A record was drawn up and put next to the heart, inside the wooden base [4].

More than fifty years later, in 1924, the Director General of the National Library, Roland Marcel notices the statue covered with dust in a storage area. After cleaning it, he installed the statue in the "*Salon d'honneur*", since then also called "the salon Voltaire", facing the courtyard, in front of the main entrance. In February 1924, the personalities of the time were invited to a ceremony to open the base (Fig. 2). The minister of education reads out loud the record that was placed in the wooden box at the moment of the donation of the heart by the heirs of the marquis de Villette in 1864. A new record was then attached to the first one and the wooden box was put back in the base of the statue [4].

The statue and its content stayed in the "*Salon d'honneur*" until their moving in May 2010 in anticipation of renovation works to be carried soon out at the site. A few days later, a strong and pungent vinegar smell was noticed. Since the wooden base of the statue was known to contain the heart of the philosopher, the management of the Library tasked its scientific laboratory to investigate the cause of the smell. The Laboratory of the Conservation Department of the BnF proposed to complement this work with an emergency plan and a new reconditioning of the heart to preserve it for future generations. The study also provided a unique opportunity to carry out an archaeometric and historical study. The heart-shaped metal box is sealed and for deontological conservation reasons, the management of the library did not give to the laboratory the authority to open it. So, indirect observation methods and non-destructive analysis or micro-sampling can give access to the content of the metal box.

The base of the statue was once again opened on July 12th, 2010, by the scientific staff of BnF's Laboratory. A condition report for the wooden box and its content following by a preventive treatment by anoxia were carried out. They undertook the scientific study used different methods. The characterization of the chemical compounds released by the different elements surrounding the heart of Voltaire was performed by Solid Phase Micro extraction (SPME) fibres, followed by gas chromatography-mass spectrometry (GC-MS) analysis. Chemical analysis of the gilded heart-shaped metal box was done by portable X-ray fluorescence (XRF). The study of the gilding and its preparation was made from a representative micro-sample. These elements were identified using scanning electron microscopy combined with energy dispersive X-ray spectrometry (SEM/EDX). The binding of the gilding was identified through specific staining test on thin cross-section. Finally, the inside of the gilded metal heart was explored using two methods of medical imaging: scanner Flash CT and scanner micro-CT Viscom 8060NDT and by endoscopy. Micro samples of the organ were collected for DNA analysis and histology.

Fig.1. Plaster model of the statue of Voltaire made by Jean-Antoine Houdon (1741–1828) containing the heart of the philosopher (© Géraldine Walter, BnF)

Fig. 2. Mr Roland Marcel, Director at the Imperial Library, holding the heart of Voltaire, whereas Mr Léon Bérard, Minister of Education reads out loud the record at the opening of the base of the statue in 1924 (© BnF)

Materials and methods

Condition report of the wooden box, the record and the heart-shaped metal box

The wooden box was brought to the laboratory and opened under chemical safety cabinet. The staff of the laboratory wore personal protective equipment to avoid sanitary risk since the state of conservation of the organ was unknown. Then the wooden box, the record and the heart-shaped metal box were examined and documented.

Studies of the metal, the preparation and the gilding of the heart-shaped metal box

Portable X-ray fluorescence (XRF)

In this study all data were collected using a handheld X-ray fluorescence spectrometer (HXRF) Niton Xlt 700 series analyser (Fondis electronic, France). The analyser features a miniaturized X-ray tube for the excitation source (38kV/10µA) and a Peltiemausoleum with a small r-cooled Si-PiN X-ray detector. Simultaneous analysis of up to 25 elements is possible. Semi-quantic concentration results are provided in parts per million (ppm, mg/kg) by data modelling using the included NDT software. Analyses completed were carried out on both sides and the welding of the heart-shaped urn. Total testing time for each XRF spot was 90s.

Scanning electron microscopy (SEM)

Two micro samples were collected to identify the materials and the gilding.

Sample N°1 was collected into a void on the gilding, on the upper part of the face bearing the inscription. This metal sample was deposited on a sample holder for direct analysis.

Sample N°2 taken near sample N°1 was mounted in embedding polyester resin and examined as polished cross-section, using microscopic methods that included UV and light microscopy. The description and location of the samples are shown in Table 1.

Table 1. SEM analyses of the heart-shaped metal box and the gilding

Sample no. and colour	Location	Stratigraphy (from bottom to top)	SEM-EDX results	Identification
Nº1 Grey	Upper part of the face bearing the inscription at the left, into a void	Metal part of the box	Pb	Lead
Nº2	Upper part of the face bearing the inscription at the left	1. Incomplete white layer (750µm)	1. Pb, O	1. Lead white
		2. White layer (750µm)	2. Pb, O	2. Lead white
		3. Red Orange Layer (700µm)	3. Al, Si, Fe + Pb, O + C, O	3. Red ochre + lead white + organic matter
		4. Layer composed of golden grains(<2µm)	4. Au	4. Gold

Major elements are noted with bold.

The samples were coated with a thin layer of carbon. The cross-section was examined with X-ray microanalysis, using a Philips XL30 CP SEM (belonging to the Musées de France's Research and Conservation Centre (C2RMF)) operating at 20Kv, at a working distance of 10nm. Qualitative elemental analysis was performed by measuring the emitted X-rays with an energy-dispersive X-ray system equipped with a Si(Li) detector and Oxford Instrument AZtec 2.1 software.

Specific staining test on thin cross-sections [6]

Specific staining test with amido black on thin cross-section of the gilding was done in addition to the elemental analysis to determine the nature of the bindings used in the different layers of the cross-section.

Setting up of a preventive treatment pending a conservation treatment

The wooden box and the gilded heart-shaped metal box containing the organ were put under anoxia with the Veloxy® system. This treatment allows treating insect infestation and avoiding the oxidative degradation until long term conservation reconditioning is set up. Both objects were sealed separately inside gas barrier plastic enclosures and connected by valves and tubes to Veloxy® which modifies the composition of the internal atmosphere by taking away the oxygen until it reaches a rate of oxygen ≤ 0.1%. Then, the valves and tubes are disconnected.

Studies of VOC

SPME fibres

The identification of the volatile organic compounds released when the statue was moved was performed by solid-phase micro extraction (SPME) fibres followed by gas chromatography-mass spectrometry (GC-MS) analysis. These methods allow for the identification of a large scale of organic molecules emitted at very low concentration. SPME is a small retractable silica fibre on which is grafted a selective porous polymeric phase. Attracted by this polymeric phase, volatiles molecules are released when the fibres are injected into the gas chromatograph at high temperature.

The day of the opening of the wooden base, six SPME fibres were used: two were placed inside the wooden base of the statue, two inside de wooden box, and two inside the hole of the heart-shaped metal box. Eight days after the opening of the base, a second campaign of sampling was led.

Table 2 lists the type of fibres used, the sampling point and the time of the sampling. Two types of fibres were chosen: Carboxen-Polydilmethylsiloxane (PDMS), adapted for the study of COV mixture of unknown compounds, and Carbowax-divinylbenzene (DVB) used to analyse polar compounds such as acids or alcohols. The fibres were exposed at two different timings: thirty and sixty minutes.

Table 2. SPME fibres and sampling conditions

Date of sampling	Sampling location	N° of fibre	Nature of the phase	Sampling times (min)
12/7/2010	Wooden base of the statue of Voltaire	Fibre 5	Carboxen/PDMS 75um	30
		Fibre 2	Carboxen/PDMS 75um	60
	Wooden box (inside)	Fibre 3	Carboxen/PDMS 75um	30
		Fibre 1	Carboxen/PDMS 75um	60
	Inside the hole of the metal heart shaped box	Fibre 6	Carboxen/PDMS 75um	60
		Fibre 7	Carbowax/DVB 70 um	60
20/07/2010	Wooden box (inside)	Fibre 6	Carboxen/PDMS 75um	60
	Inside the hole of the metal heart shaped box	Fibre 7	Carbowax/DVB 70um	60

GC-MS

A Shimadzu GC (Shimadzu, QP2010plus) was used to analyse COV samples extracted by SPME fibres. A Supelco 5MS column (30m x 0.25mm i.d., 0.25µm film thickness) was installed in the GC and helium was used as the carrier gas with a flow rate of 1.46mL/min. The initial oven temperature was 80°C for 2min, followed by ramping at 10°C/min to 300°C, and maintained for 5min. For SPME fibres desorption, the injector temperature was set at 250°C. The spectrometer used was a Fourier Transform infrared spectrometer (Spectrum 2000, Perkin Elmer, scanning 600–4000cm^{-1}) equipped with an ATR accessory (attenuated total reflectance).

Exploration of the interior of the heart-shaped metal box by medical imaging

As the opening of the heart-shaped metal box was out of question, exploration methods had to be found among non-destructive, medical ones. The relative thinness of the lead box pointed toward X-ray imaging for exploring its content. Two types of Computed Tomography (CT) scanners were used: medical scan (CT) and industrial micro-CT, most recent and efficient in their operating range.

Flash CT scanner

At first, trials were done with a medical scanner: Scanner Flash CT located at the Centre Chirurgical Marie Lannelongue, Paris. This model was considered appropriate due to its double X-ray tube allowing for dual energy X-ray acquisitions, powerful with metallic artefacts. A specialist in cardiac medicine attended and was in a position to provide medical advice about the state of conservation and structures of the organ.

Micro-CT Viscom 8060NDT Scanner

A second test was performed with a micro CT Viscom 8060NDT Scanner. This device dedicated to industrial applications has high energy X-ray source which enables going through metal.

Tissue sample analysis

Histology

The internal exploration of the heart-shaped metal box was performed using a 2.4mm diameter flexible endoscope, designed for routine diagnostic in ear, nose and throat pathologies with children. The endoscope was passed through the pre-existing hole of the box. Two biopsies were done using a micro ear forceps. Samples were immediately fixed in Bouin's fluid and then fixed in formalin (10%) and embedded in paraffin. Sections of 8 µm were stained with hematein-eosin-saffron (HES) and a serial section subjected to immunohistochemistry. The latter were stained by an indirect immunofluorescence technique using monoclonal antibodies against desmin (clone D33, Dako), vimentin (clone Vim3B4, Dako), myosin (clone 414, Abcam) and MY-32 (MY-32, Sigma-Aldrich). MY-32 antibody recognizes skeletal muscle myosin and specifically the fast twitch (type II) isomyosin molecules of the heavy chain of myosin.

DNA mitochondrial analysis

This analysis was performed at the Laboratoire des Empreintes Génétiques BIOMNIS, in Lyon. The typing of DNA mitochondrial was performed by sequencing with DNA Big Dye Terminator Sequencing kit (Applied Biosystems) using 15997 and 00029 as sequencing primers. Sequences were compared to reference sequence called Cambridge Reference Sequence or CRS.

Results and discussion

Condition report of the wooden box, the record and the heart-shaped metal box

At the opening of the box, a very strong vinegar smell came out, suggesting that the heart had been preserved in an alcoholic solution. Inside the wooden box a gilded metal heart was found bearing the following inscription: "Le Coeur de Voltaire mort à Paris, le XXX. May MDCCLXXVIII". Over the heart rested the record (Fig. 3) of the donation to the Imperial Library, dated December 1864 and signed by Victor Duruy and Léon Duval. However, the record dated February 1924 was missing.

Description of the wooden box

The dimensions of the wooden box are as follows: 32cm length, 21.5cm width, and 20.5cm height. The box interior is upholstered in purple fabric showing numerous traces of discoloration. Amongst the debris found inside the wooden box was a fragment of an exuviated of Dermestidae (most probably from *Anthrenus* sp.). As no other specimen was found in the box, it has not been possible to make a more precise identification. Beside this little fragment no other sign of biocontamination or material deterioration of the wooden box and the textile was found.

Fig. 3. The heart-shaped metal box and the folded record inside the wooden box opened in July 2010 (© Géraldine Walter, BnF)

Description of the record

A very strong smell of acetic acid emanated from the record (4 white leafs sewn with a green ribbon, 320×210mm) at the moment of the opening of the wooden box. The pH of the record was measured (pH = 4.7). The record (Fig. 4) was digitized and can be consulted on the BnF site (http://gallica.bnf.fr)

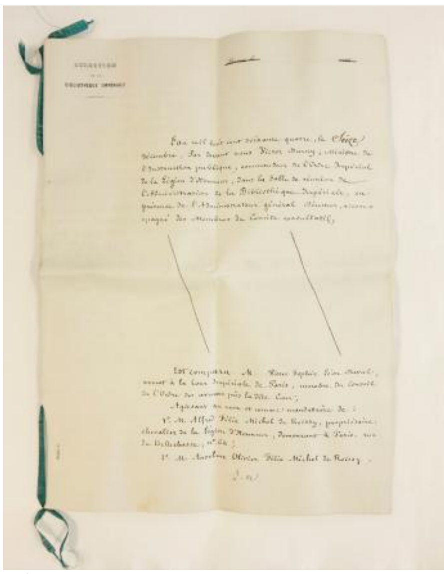

Fig. 4. Record of the donation to the Imperial Library, dated December1864 and signed by Mr Victor Duruy and Mr Léon Duval (© Géraldine Walter, BnF)

Description of the gilded heart-shaped metal box

The metal box weighs 3kg. The metal box is 22cm high and 18cm at its widest part (Fig. 5a and b). The gilded surface of the box wears numerous abrasion marks. Small holes in the gilding allow having a glimpse at the grey metal. A hole with a diameter of approximately 3mm and a thickness of 2–3mm was observed on the face side of the metal box. This hole was probably done to introduce the conservation solution inside the metal box. The cork used to close the hole hermetically has disappeared. The organ was no longer in solution in the metal box and seemed to have dried out.

Fig. 5. The heart-shaped metal box: a. front view; b. view from the back (© Géraldine Walter, BnF)

Studies of the heart-shaped metal box, the preparation and the gilding

XRF

The analysis made on the surface revealed a high presence of lead (Pb) reflecting the traditional funeral urn employed at that time to preserve human remains and explaining the heavy weight observed. The heart-shaped metal box presents also typical lead corrosion products (white lead carbonate) [7, 8] over the metal surface. Iron (Fe) and to a lesser extent antimony (Sb) were also detected. The antimony in its lead alloy increases the hardness and gives resistance to corrosion. In lead-antimony alloy, antimony additions increase hardness, tensile strength and fatigue resistance [9]**.** The welding of the urn is characterized by the major occurrence of tin (Sn) and the absence of antimony. Welding is generally made of metal alloys with low melting point (usually tin and lead). The presence of Sn and Sb is classically found in poorly purified lead from the Middle Ages. A wide range of commonly-used alloys, such as *Pewter* (a Sn/Pb with a high Sn content) and *Britannia* metal (high Sn content Sb and Cu), develop either warts of corrosion or disfiguring thick, cracked, and crusty layers [10]. Gold (Au) was not detected by the XRF (under limit of detection).

SEM and specific staining test on thin cross-sections

A comprehensive view of the analytical information obtained from EDX spectra is given in Table 1. In addition to the XRF analysis, the SEM analyses confirm that the material used in the making of the metal box is lead (sample Nº1, Table 1). A white lead preparation was put on the heart-shaped lead box prior to the gilding. This preparation was applied in two thick layers of 750µm each (Table 1, Fig. 6).

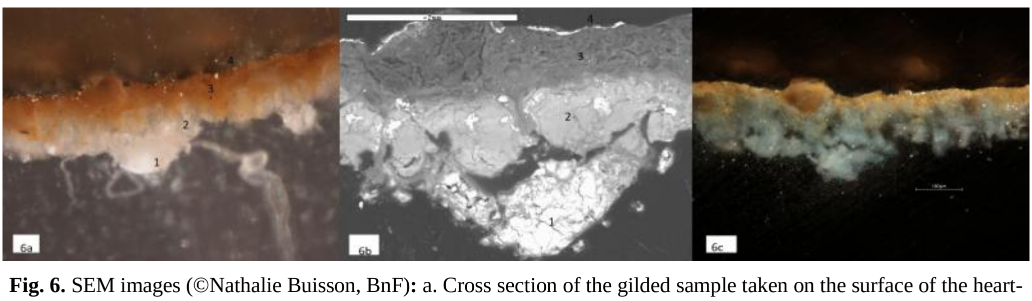

Fig. 6. SEM images (©Nathalie Buisson, BnF)**:** a. Cross section of the gilded sample taken on the surface of the heart-shaped metal box (20×); b. The gilded sample (1000×), Layer 1-lead white, layer 2-lead white, layer 3-gilding bole made of red ochre, layer 4-gold leaf; c. Cross section of the gilded sample taken on the surface of the heart-shaped metal box (20×), after specific staining test on thin cross-sections using amido black (NA2)

Carefully sanded, the preparation masks the metal surface irregularities and isolates the pictorial layer or the gilding. A specific staining test on thin cross-sections using amido black (NA2) revealed the presence of a protein-containing binding agent. Indeed, after this test, the withe layers (corresponding to layers 1 and 2 of the Figure 6) turned blue, showing the presence of a protein binding material.

Gold leaf gilding is applied on a red orange gilding bole made of ochre mixed with minium (layer 3, Fig. 6). It was not possible to determine exactly the type of binding used. However, the absence of coloration of the red orange layer (layer 3 of Fig. 6) suggests that the binding could be an oil-based binding agent.

Setting up of a preventive treatment pending a conservation **reconditioning**

Anoxia was chosen as a preventive treatment [11, 12] to slow down the oxidative degradations of the heart-shaped metal box and the organ it contains. Anoxia also presents the advantage of curing the potential infestation of the organ due to the presence of the exuvia. Plastic enclosures were kept in a room with controlled environment pending a definitive conservation reconditioning.

Studies of VOCs

The nature of the VOCs emitted by the wooden base, the wooden box and the organ is the same. For example, see chromatogram 1(Fig. 7a) and 2 (Fig. 7b).

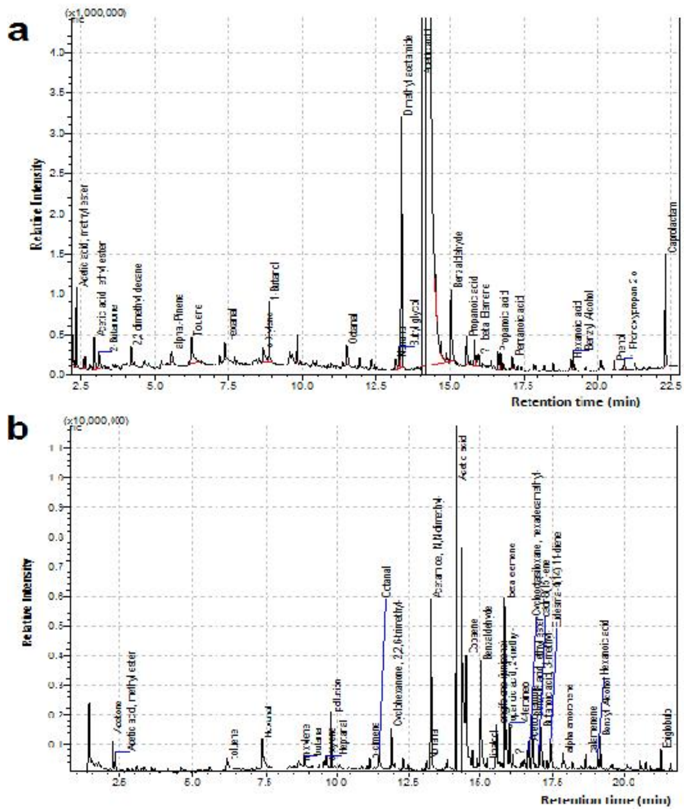

Fig. 7. Chromatograms 1 and 2: a. GC-MS chromatogram of COV adsorbed on SPME Carboxen/PDMS N°1 fibre exposed 60 min to COV present inside the wooden box; b. GC-MS chromatogram of COV adsorbed on SPME Carboxen/PMDS N°6 fibre exposed 60 min to COV present inside the heart-shaped metal box (© Thi-Phuong N'guyen)

Acetic acid was largely predominant as evidenced by the saturation of the peak. The presence of other acids, in particular hexanoic and propanoic acid and ester-like derivatives from acetic acid, such as methyl and ethyl acetate were also detected. A series of complete linear aldehydes, such as butanal, pentanal, hexanal, heptanal, octanal, nonalal and decanal and benzaldehyde were also found. Aromatic hydrocarbon as o-, p-, m-xylene, ethylbenzene and toluene were identified. Finally, dimethylacetamid, which is likely a pollutant present in the atmosphere of the laboratory, was also identified.

From the organ, in addition, nearly forty different terpene derivatives, odorous molecules from resin plant were detected. These were particularly visible on chromatogram 3 (Fig. 8) obtained from Carbowax/DVB fibre. For visibility purpose, this chromatogram is presented in two parts.

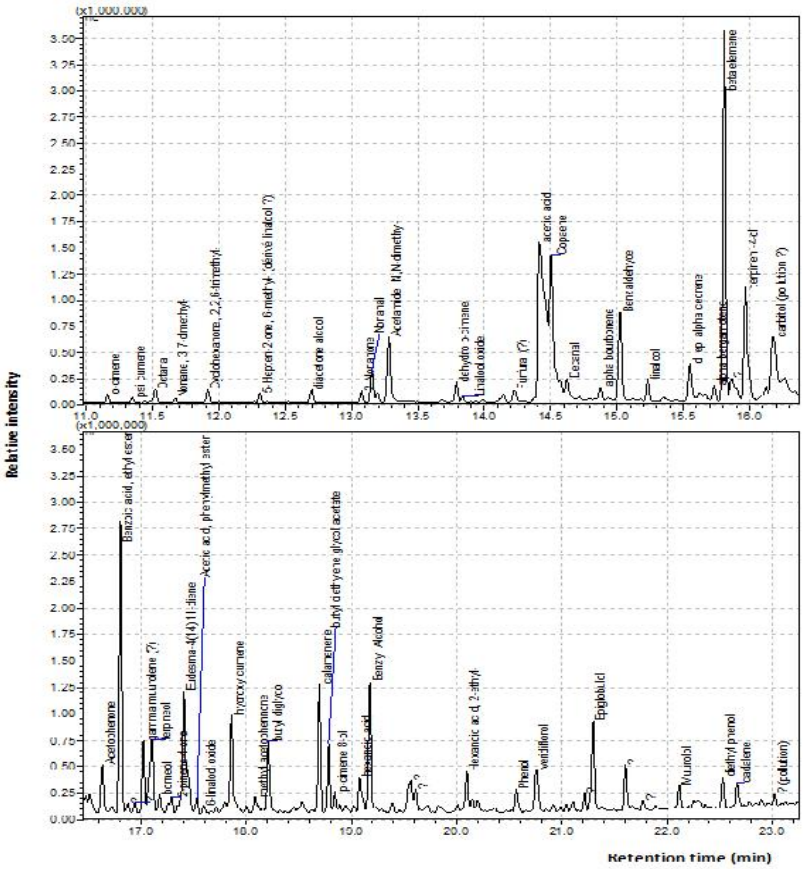

Fig. 8. Chromatogram 3: GC-MS chromatogram of COV adsorbed on SPME fibre CarboWAX/DVB Nº7, placed 1 hour inside the small hole of the metal heart-shaped box (© Thi-Phuong N'guyen)

Some of these compounds were identified using reference products known as embalmment products of this period (turpentine, resins and essential oils) [13]. These COVs analyses reveal that the apothecary Mitouard used an alcoholic solution in presence of essential oils, essence or cedar rosin (a cedrene, diepicedrene, thujopsene, epicedrol) or lavender extracts (linalool, terpinene-4-ol, ocimene, terpineol).

The heart's preparation technique could not be fully elucidated due to the decision not to open the metallic box.

Exploration of the interior of the heart-shaped metal box by medical imaging

Flash CT Scanner

X-rays were not sufficiently penetrating to enable visual perception of the content of the heart-shape lead box or to assess the state of conservation of the heart.

Micro-CT Viscom 8060NDT Scanner

A second test was performed with a micro CT Viscom 8060NDT Scanner. The energy produced by this scanner is high enough to go through metals like lead. Unfortunately, at this level of energy, soft tissues, such as the heart, become radiotransparents. Thus it was not possible to obtain an image of the organ inside the metal box. At first glance the thickness of the lead layer of the box was not uniform. Nevertheless it was not possible to carry out a complete study of the scan images which could provide information about weaker zones of the box and that would have indicated that a fluid reconditioning was conceivable.

Tissue sample analysis

Histology

As the organ is firmly attached to the box, only a small portion (5 to 6cm in size) of the organ was observable. This portion appeared stony and dry, associated with undefined inorganic debris.

Histological sections showed numerous vegetal particles associated with striated muscle fibres, all damaged (Fig. 9a and b). In these fibres, long spindle cells with striation were noted, but no nucleus could be observed. Other samples appeared necrotic. Immunohistochemistry study using the anti-desmin antibody (Fig. 10) showed a weak staining in the striated muscle cells. This result has to be interpreted with caution, given the state of decomposition of the sample. Staining using the anti MY-32 was negative. Staining using the anti-myosin and the anti vimentin antibodies were both unspecific. Therefore, it was not possible to confirm that striated muscle samples belonged to a cardiac tissue. Vegetal particles give an additional indication that the heart had been embalmed.

DNA mitochondrial analysis

A DNA mitochondrial analysis was performed to offer information which could have been interesting for possible relatives of Voltaire. Unfortunately, the samples were too deteriorated to provide a profile useful for the descendants. Nevertheless, further analyses could provide better results, should future technology enable the opening of the metallic box and a less deteriorated sampling zone be selected.

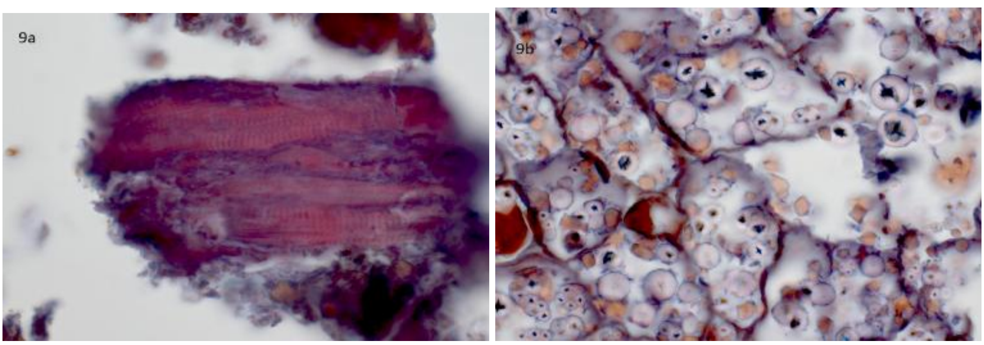

Fig. 9. Representative stained biopsy histology (HES) is presented at 100× original magnification: a. The aspect is compatible with striated muscle fibres. Presence of long spindle cells with striation, no nucleus can be observed; b. presence of diverse unidentified vegetal fragments (© Cécile Badoual)

Fig. 10. Representative view of the immunohistochemical study using the anti-desmin antibody, presented at 400× original magnification. Weak brown staining is observed in the striated cells (© Cécile Badoual)

Conclusion

The results have provided an explanation for the origin of the vinegar smell and confirmed that Voltaire's heart was preserved in an alcoholic solution, also called at that time "spirit of wine". Literature on anatomical preparations conserved in lead boxes reports that these practices were common for symbolic organs such as the heart of well-known personalities until the nineteenth century [14-18]. For example, Gannal reports the preparation of Madame la Dauphine's heart by Riqueur, apothecary of the King : "The heart, after being emptied, washed with spirit of wine and dried, was placed in a glass vessel with the liquor ; the same organ, having been filled with a balm made of cinnamon, cloves, myrrh, styrax and benzoin, was enclosed in a bag of oilcloth, which was placed in a heart-shaped lead container or a box, which was immediately welded to be given to the Duchess of Arpajon " [17].

A scientific committee composed of specialists in archaeometry, science museology, physiology, anatomical collections and preventive conservation has been set up to validate a reconditioning procedure of the organ and the metallic box. On the basis of results of this study, two propositions were submitted to the scientific committee:

– to refill the metallic box with ethanol as the apothecary Mitouard did two centuries before. This method presents the dual advantage of preserving the original conditioning of the organ and to offer a hermetic environment to prevent oxidation degradation. Formalin was not considered as a valid option since it did not exist in Voltaire's time and also because it is now prohibited due to its effect on DNA [19]. This method must follow a very strict protocol which consists of increasing the concentration of ethanol from 40% to 80% [20-22].

– to let the dried organ inside the metallic box enclosed in the wooden box as it was discovered in the wooden base of the Voltaire's statue.

However, the scientific committee recommended ensuring the physical integrity of the metal box in order to prevent any risk of fluid leakage in future. As the scan tests did not release any new information about the zones of weakness of the metal box, the scientific committee recommended following the second option. However, to avoid oxidative damage and the release of acetic acid vapour, this option will have to be completed by static anoxia. This anoxia will be performed by sealing in plastic gas barrier the metallic box with oxygen scavengers. In order to avoid the emission of odour released by the wooden box, activated carbon filters will be added inside the base of the statue. This solution was chosen because it is the one that entails the least direct intervention on the organ, and because it will prevent or slow down any oxidative damage from the inner lining of the metal box.

It is planned to verify the state of the reconditioning regularly and change the oxygen scavengers as needed. In addition, a new record relating the opening of the base of the Voltaire's statue of July 2010, indicating the results of the analysis and the anoxic preventive treatment, as well as the reconditioning procedures will be placed inside the wooden box beside the heart.

Renovations of the Richelieu site of the BnF provided a unique opportunity to conduct a multidisciplinary study of the heart of Voltaire, while addressing the full range of challenges that arose in its long term conservation.

Acknowledgements

The authors would like to thank all the members of the scientific committee: Christophe Degueurce, Curator of the Fragonard Museum and Prof. at Ecole Nationale de Médecine Vétérinaire, Maison-Alfort, Luc Robbiola, Laboratoire TRACES (CNRS UMR 5608) and Michel Van Praët, Conservateur en Chef at l'Inspection générale des musées, Professor at the *Muséum national d'Histoire naturelle* in Paris for their expert advice and their great availability.

The authors would like to acknowledge Victoire Bouveau for technical assistance. They also are very thankful to Valentin Rottier from the conservation laboratory of the *Bibliothèque nationale de France* for having carried out the anoxia. They are also grateful to Marie-Hélène Sherpin from the *Laboratoire des Empreintes Génétiques* BIOMNIS who did the DNA mitochondrial analysis, Thi-Phuong N'guyen who performed the COVs analysis and Arnaud Marchadier who did the CT Scan tests.

References

[1] Voltaire, **Œuvres complètes de Voltaire avec des notes et une notice sur la vie de Voltaire par Condorcet,** Garnier, Paris, 1877.
[2] C. Portier-Kaltenbach, **Histoires d'os et autres illustres abattis, morceaux choisis de l'histoire de France**, JC Lattès, Millau, 2010, p.113.
[3] G. Desnoiresterres, **Voltaire et la société Française au XVIIIe siècle**, Didier, Paris, 1867.
[4] **Bulletin et mémoires de la société archéologique et historique de Clermont-de-l'Oise, années 1927-1928,** Imprimeries réunies de Senlis, 1931, pp. 63-64.
[5] L. Auvray, *Chronique des Beaux-Arts*, **Revue artistique et littéraire, VII,** 1864, p.145.
[6] E. Martin, *Some improvements in techniques of analysis of paint media*, **Studies in Conservation, 22,** 1977, pp. 63-67.
[7] J. Tétreault, J. Sirois, E. Stamatopoulou, *Studies of lead corrosion in acetic acid environment*, **Studies in Conservation, 43**(1), 1998, pp.17-32.
[8]. J. Tétreaul, E. Cano, D.A. Scott, *Corrosion of copper and lead by formaldehyde, formic and acetic acid vapours,* **Studies in Conservation, 48**(4), 2003, pp. 237-250.
[9] S.J. Alhassan, F.E. Godwin, *Lead and Alloys,* Chap. 45, **Corrosion Tests and Standards: Application and Interpretation,** (Editor: R. Baboian), ASTM International, Baltimore, 2005, pp. 531-536.
[10] J.F. DeMouthe, **Natural Materials: Source, Properties and Uses**, Routledge, Oxford, 2006, pp. 28-30.
[11] N. Valentin, *Comparative analysis of insect control by nitrogen, argon and carbon dioxide, in museum, archive and herbarium collections,* **International Biodeterioration and Biodegradation, 32**(4), 1993, pp. 263-278.
[12] N. Valentin, F. Preusser, *Insect control by inert gases in museum and archives,* **Restaurator, 11**, 1990, pp. 22-33.

[13] C. Degueurce, S. Vo Dhui, J. Bleton, P. Hugon, L. Cadot, A. Tchapla, *Un mystère: la technique de conservation mise en œuvre par Honoré Fragonard pour créer ses fameux écorchés*, **Bulletin de la Société Française d'Histoire de la Médecine et des Sciences Vétérinaires, 8,** 2008, pp. 40-57.
[14] C. Régnier, *The heart of the kings of France: cordial immortality*, **Medicographia, 31**(4), 2009, pp. 430-439.
[15] J.A. Chroscicki, M. Hengerer, G. Sabatier, **Les funérailles princières en Europe, XVIe-XVIIIe siècle: Le grand théâtre de la mort**, Editions de la Maison des Sciences de l'Homme, Paris, 2012.
[16] G.-L. [Leclerc Comte de] Buffon, L.-J.-M Daubenton, **Pièces d'anatomie conservées dans des liqueurs, Histoire Naturelle générale et particulière: avec la Description du Cabinet du Roy,** Imprimerie Royale, Paris, 1749, pp. 171-192.
[17] J.-N. Gannal, **Histoire des Embaumements et de la préparation des Pièces anatomiques**, Seconde édition, Chez l'Auteur et Chez Desloges, Paris, 1841, 448p.
[18] P. Boitard, **Nouveau manuel complet du naturaliste préparateur suivi d'un traité des embaumements**, Roret, Paris, 1852.
[19] A. Péquignot, E. Sarot, F. Duranthon, A. Pensel, M.F. Carillo Baraglioli, *Fixation specimen without formalin in natural history collections: Utopia or Reality? ,* **ICOM-CC, 16th Triennial Conference**, **Lisbon**, 19-23 September 2001, (Editor J. Bridgland), Lisbon, 2011, pp. 1-10.
[20] J. Bayless, C. Shepherd, *Removing wet specimens from long-term storage in formalin*, **Conserve O Gram, 11**(1), 1993, pp. 1-4.
[21] S. Moore, **Fluid Preservation, Care and conservation of Natural History Collections,** (Editors D.J. Carter and A. Walker), Oxford, 1999, pp. 92-132.
[22] J.E. Simmons, *Storage Concerns for Fluid-Preserved Collections*, **Conserve O Gram**, **11**(3), 1999, pp. 1-4.

Received: June 01, 2016
Accepted: February 17, 2017