Study the Negative Effects related to Inappropriate Storage Conditions on Archaeological Ceramic, Indicate Some Practical Solutions

دراسة التأثيرات السلبية المرتبطة بظروف التخزين غير المناسبة للسيراميك الأثري، مع توضيح بعض الحلول العملية

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Abstract

This paper studies the negative effects of storage conditions on archaeological ceramic artifacts since they may spend much of their lives in storage areas and units (in the excavation or Museums). The ceramic artifacts are subject to deterioration from chemical interactions to some extent between the main matrix of it and the surrounding deterioration factors in these areas and units or sometimes happen from the materials used in treatment steps as old or new restoration. Thus, archaeological ceramic artifacts can be unstable even over short periods. Maintaining the proper environment, like control of light, temperature, relative humidity, ventilating, air pollutants, and pests inside the storage areas and units, is required. So diligent and continuous observation of these conditions is required. In addition, these areas must be adequate to accommodate the particular characteristics and quantity of objects. The paper studies some affected ceramic samples through different investigative and analytical methods to recognize the harmful deterioration effects, such as **Digital Optical Microscope** to investigate the destructed ceramic artifacts, **The Scanning Electron Microscope equipped with the Energy Dispersive system (SEM-EDX)** detailed ceramic surface composition and its initial structure. **X-Ray Diffraction (XRD)** recognizes the mineral composition and crystalline phases in ceramic; in addition, **Differential Thermal Analysis (DTA)** determines the almost firing temperature of ceramic artifacts. This study evaluates the different deterioration aspects of archaeological ceramic artifacts; it gives some practical solutions to avoid a high percentage of deterioration problems before it happens by providing an appropriate storage environment, materials, and units.

Keywords: Storage Conditions, Storage Areas and Units, Safe Storage, SEM-EDX, DTA

الملخص

تتناول هذه الدراسة الآثار السيئة لظروف التخزين على القطع الأثرية الفخارية والخزفية التي ربما تظل فترات طويله في مناطق ووحدات التخزين (في الحفائر أو المتاحف). وتتعرض الآثار الفخارية والخزفية للتلف من خلال التفاعلات الكيميائية ما بين المكون الأساسي لها وعوامل التلف المحيطة بها في هذه المناطق أو الوحدات، كما يحدث التلف أحيانا من المواد المستخدمة في خطوات العلاج كترميم قديم أو حديث. وهكذا تكون المشغولات الفخارية والخزفية الأثرية غير مستقرة حتى على مدى فترات قصيرة. ويجب الحفاظ على البيئة المناسبة من حيث التحكم في الضوء، ودرجة الحرارة، والرطوبة النسبية، والتهوية، وملوثات الهواء، والحشرات داخل مناطق ووحدات التخزين. لذا تلزم المتابعة الجادة والمستمرة لهذه الظروف المحيطة. بالإضافة إلى ذلك يجب أن تكون هذه المناطق كافية لاستيعاب المقتنيات بالأحجام والخصائص المميزة والمختلفة. تناول البحث دراسة بعض العينات الأثرية التي تعرضت للتلف من خلال طرق فحصية وتحليلية مختلفة للتعرف على آثار التلف السيئة بها، مثل الميكروسكوب الضوئي الرقمي **Digital Optical Microscope** لفحص المقتنيات التالفة، والميكروسكوب الإلكتروني الماسح المجهز بنظام تشتيت الطاقة **(SEM-EDX)** الذي يعطى معلومات حول سطح المقتنيات الفخارية والخزفية وبنيتها الداخلية. واستخدمت حيود الأشعة السينية **(XRD)** لتحديد التركيب المعدني والأطوار المتبلورة لها،

بالإضافة إلى التحليل الحراري التفاضلي **(DTA)** حيث تلعب هذه الطريقة دورا مهمًا في تحديد درجة حرارة الحرق التقريبية للمقتنيات الفخارية والخزفية. تقيم هذه الدراسة جوانب التدهور المختلفة للقطع الأثرية الفخارية والخزفية، وإعطاء بعض الحلول العملية لتجنب نسبة عالية من مشاكل التلف قبل حدوثها، من خلال توفير بيئة ومواد ووحدات تخزين مناسبة.

الكلمات الدالة: ظروف التخزين، مناطق ووحدات التخزين، التخزين الآمن، الميكروسكوب الإلكتروني الماسح SEM-EDX، التحليل الحراري التفاضلي DTA

1. Introduction

1.1 The Aim of this study

This study points to the bad effects of storage conditions on archaeological ceramic artifacts, which can be unstable and deteriorate even over a short time in storage areas and units by physical and chemical reactions with surrounding deterioration factors. On the other hand, this deterioration happens from the treatment and conservation of materials as old or new restoration. There are many kinds of stores like the **Archaeological site store - Archaeological Museum store -** and **Expeditions store**. Store buildings may be designed and constructed incorrectly in the wrong place or for a long time. The store is usually subjected to many deterioration factors, like the high level of underground water or drains from the surrounding inhabited areas, the effect of cover plants[1], the effect of rains, and changes in temperature degrees or relative humidity **(Fig. 1, 2, 3, 4)**. Also, the storage units may initially be crowded, have many disadvantages, and be subjected to many deterioration factors like insects and micro-organisms; in addition to contaminants, sometimes the storage units are made of bad materials.

Fig. 1

Fig. 2

Fig. 1, 2 Show the deteriorating factors which affected excavation areas and the storage places on them (The clear effect of RH and drain). After: **Müller, (2011)**[2].

[1] Kelly, Kenneth, G., et al., *Compositional analysis of French colonial ceramics: implications for understanding trade and exchange*, Journal of Caribbean Archaeology, 2008, pp. 85-108.
[2] Müller, Vera et al., *Report on the excavations at Tell el-Dab'a, Egypt and the Levant,* Published By: Austrian Academy of Sciences Press, 2011, pp. 17-53.

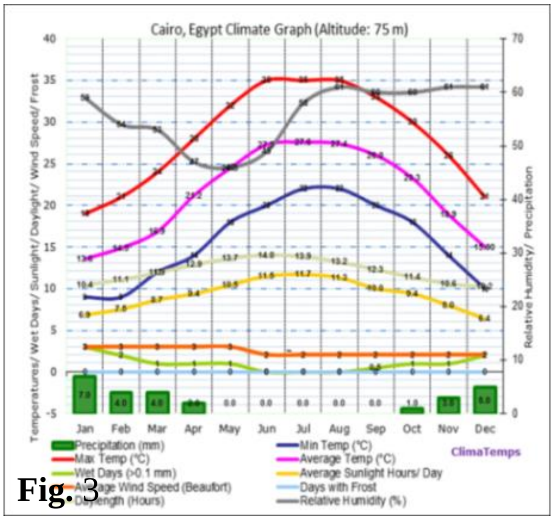

Fig. 3

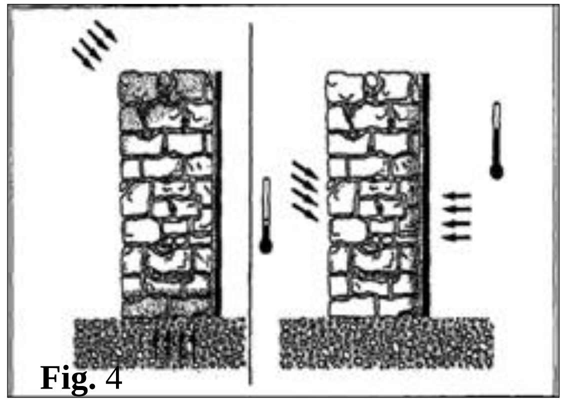

Fig. 4

Fig. 3, 4 Show the climate changes in Cairo as an example in Egypt;
In addition, the effects of salt crystallization on the walls of the store of artifacts.
(3) After: **http:// geographyprojectegyptweatherandclimate, (2018)**[3].
(4) After: **Berducou, M., (2002)**[4].

So that it is important to save and maintain the proper environment in the storage places (Areas and units), like control of light, temperature, relative humidity, ventilating, air pollutants[5], insects, and pests. It is important to choose the model units to store different ceramic artifacts, so diligent observations of these conditions are required; in addition, these areas must be adequate to accommodate the particular characteristics and quantity of objects. It is also important to give practical, simple solutions to avoid many storage problems before it happens by providing an appropriate storage environment, appropriate storage materials, and appropriate storage units **(Fig. 5, 6, 7, 8) (Tab. 1)**.

Three small samples representative of deteriorated archaeological ceramics artifacts were chosen from three different storage areas **(Matria**, **Fustat**, and **Helwan)**, To determine and evaluate the extent of the bad storing condition which affected these different samples and to get data about its component and their technological information.

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[3] http://geographyprojectegyptweatherandclimate.weebly.com/climograph.html, 2018.
[4] Berducou, Marry, *Preservation in Archaeological Science*, Institute Francais d´Archaeologie Oriental, le Caire, 2002, p. 447.
[5] Green, R., Thickett, D., *Testing Materials for Use in the Storage and Display of Antiquities: A Revised Methodology*, Source: Studies in Conservation, 1995, Vol. 40, No. 3, pp. 145-152.

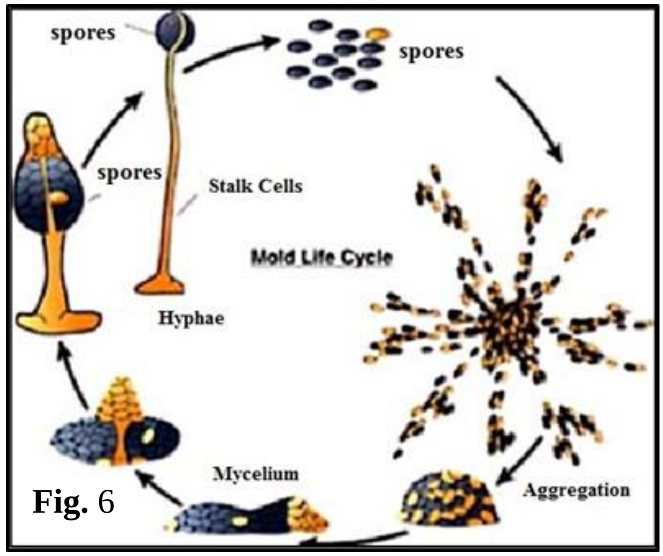

Fig. 5, 6 Show one of a bad-fired ceramic object deteriorated by the mold life cycle.
(5) After: **Salatnia, A., (2010)**[6]; **(**6) After: **Berger, S., (2013)**[7].

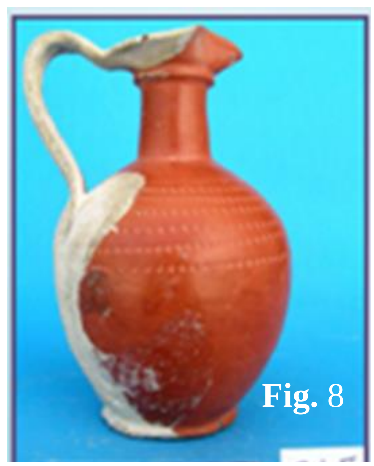

Fig. 7, 8 Show an untidy and crowded store for artifacts and one of the ceramic jars with distorted restoration.
After: **Salatnia, A., (2010)**[8].

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[6] Salatnia, A., *Phoenician settlements - Punic in The western basin of the Mediterranean Sea*, PhD thesis in Ancient History, 2010, p. 198.
[7] Berger, Stephanie, *Treating Bones*, The Intersection of Archaeology and Conservation, University of Michigan, 2013, p. 37.
[8] Salatnia, *Phoenician settlements - Punic in The western basin of the Mediterranean Sea*, p. 247.

Tab. 1 Show general Museum storage deterioration factors.
After: **Berger, S., (2013)**[9].

Agents of Deterioration	Effects
Incorrect Temperature	Significant structural, surface, chemical and biological damage - disfigurement
Incorrect Humidity	Major structural, surface, chemical and biological damage - disfigurement
Physical damage	Structural and surface damage - disfigurement
Water	Major structural, surface, chemical and biological damage - disfigurement
Human Interaction	Major structural, surface, and chemical damage - loss of the object - disfigurement
Fire	Major structural, surface, and chemical damage - loss of the object - disfigurement
Pests	Major structural, surface, and chemical damage - loss of the object - disfigurement
Contaminations	Surface, chemical and biological damage - disfigurement
Radiation	Disfigurement - chemical and surface damage - physical weakening

[9] Berger, *Treating Bones*, The Intersection of Archaeology and Conservation, p. 33.

1.2 bad store conditions in storage areas and units:

Deterioration of ceramic object extent before excavation, since the absence of light and changing RH generally do not affect ceramics, but soil PH may. Ceramic, being porous, contains an infinitely large number of tiny pores **(Fig. 9)**. Through capillary action, these can absorb the water and salts previously dissolved in it right into the core of the object[10].

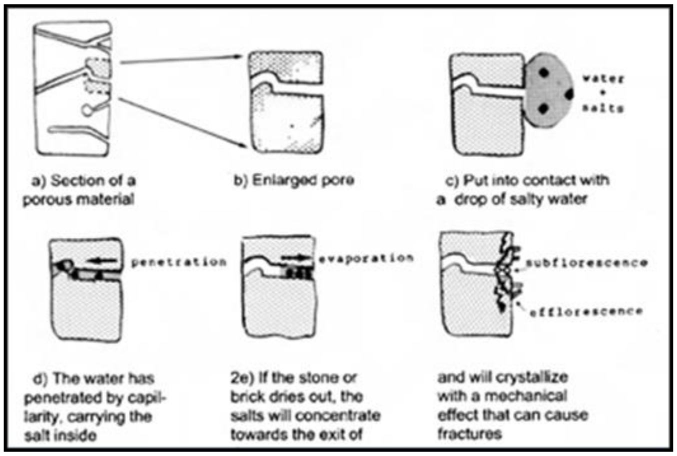

Fig. 9 the effect of salts on the porous ceramic object After: **Guichen, G., (1995)**[11].

Ceramic objects recovered from different soil traces must be marked with the sample identifier to recognize the kind of soil and what it is content, like salts or crusts[12]. All soils contain high and low amounts of soluble salts. If the soil is close to the sea or part of an old marine deposit, the amount of sodium chloride is especially high. Salts can also be introduced artificially through fertilizers and salt stores or through the de-icing of roads in cold countries, by spreading mixtures of chlorides, etc.[13].

This crystallization can sometimes happen beneath the solid surface of an object. Moreover, exert pressure inside the pores at the moment of crystallization which may burst them, resulting in a surface flaking of the object to a greater or lesser extent. Crystallization can also occur on the surface of an object, which will be covered with a whitish deposit[14, 15].

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[10] Stanley-Price, Nicholas, *Conservation on Archaeological Excavations with particular reference to the Mediterranean area*, ICCROM, Rome, Italy, 1995, p. 4, 5.
[11] Guichen, Gaël, *Object interred*, Object disinterred, ICCROM, Rome, Italy, 1995, pp. 21-28.
[12] *A Standard for Pottery Analysis in Archaeology*, Prehistoric Ceramics Research Group, Medieval Pottery Research Group, Study Group for Roman Pottery, 2015, p. 2- 41.
[13] Stanley-Price, *Conservation on Archaeological Excavations*, p. 33.
[14] Kelly, *Compositional analysis of French colonial ceramics*: pp. 85-108.
[15] Stanley-Price, *Conservation on Archaeological Excavations*, p. 32, 33.

It is essential to remember that insofar as a porous object contains soluble salts, they will move in the object according to the variations in the RH of the air. The process of dissolution, crystallization, re-dissolution and re-crystallization will cause micro-cracks in the object and accelerate its disintegration. Several archaeological ceramics objects on display or in storage collections; provide numerous examples of that[16, 17].

1.3 bad storing and worse handling:

Destruction or deterioration happens to ceramic objects by natural and human factor agents like worse handling[18], so you must follow important points to avoid this deterioration by fault storing practices. The majority of ceramics can be marked by writing on the sherd or vessel's inside surface. Use permanent black or white ink as needed to contrast with the colour of the surface. Mark the surface of the sherd, not on shattered areas that might eventually be put together, in a small, legible font. Be careful not to mark on top of decorations, use markings, or surface residues. Direct marking is not possible on some ceramic items. For instance, it may be too tiny, too friable, or it may have been kept without being washed. It needs to be packaged in polythene bags that are the suitable size, strength, and have holes punched in them to let the contents "**breath**". Sherds do not cram into bags that are too tiny and huge, hefty sherds (like stoneware) do not bag with little, fragile sherds (such as porcelain). Tissue paper devoid of acids must be used to wrap delicate sherds[19, 20]. The same type of pottery objects should be collected together in separate bags. Two or more anti-mold labels can also be placed in each bag. The site's name and the types of finds it contains should be written on the outside of the bag - indexed, besides writing what distinguishes features of the inside samples. Moreover, any other information requested by the restoration laboratory or store must be added. It prefers to use external permanent ink; **ceramic sherds can be fumigated with Ammonia and Ethyl Alcohol 1:3**[21, 22].

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16 Stanley-Price, *Conservation on Archaeological Excavations*, p. 32, 33.
17 Berducou, Marry, *Preservation in Archaeological Science*, p. 94.
18 Guichen, *Object interred*, Object disinterred, pp. 21-28.
19 Thickett, D., Lee, R., *Selection of Materials for the Storage or Display of Museum Objects*, the Trustees of the British Museum, Occasional Paper No.111, London, 2004, pp. 1-30.
20 *A Standard for Pottery Analysis in Archaeology*, 2015, p. 2- 41.
21 Berger, *Treating Bones, The Intersection of Archaeology and Conservation*, p. 60.
22 Majewski, Janice, *Smithsonian Guidelines for Accessible Exhibition Design*, Smithsonian Accessibility Program, 2001, pp. 1-20.

2. Experimental procedure:

The archaeological ceramic artifacts are subjected to many bad effects and deterioration factors of storage conditions in storage areas and units (in the excavation or the Museums) since these archaeological ceramic artifacts objects left there for long periods in almost fault constructed design buildings[23]. Three small samples representative of deteriorated archaeological ceramics artifacts were chosen from three different storage areas **(Matria, Fustat, and Helwan) (Fig. 10, 11, 12)**. The First sample **(Matria store)** is from the unglazed ceramic object and dark brown color body matrix; it contains a high percentage of organic additives and is covered with a white slip layer. The Second sample **(Fustat store area)** is from a green-glazed object and the light gray color body matrix. Furthermore, the Third sample **(Helwan store)**, like Matria`s sample, is unglazed and has a thin layer of white slip from inside and outside surfaces; it has a brown color body matrix; these different samples appeared in many deterioration aspects by visual investigation.

Fig. 10, 11, 12 Show the three small samples from three different storage areas **(Matria, Fustat, and Helwan)**

To determine and evaluate the extent of the bad storing condition which affected these different samples, and to get data about its component and its technological information (which have important roles in this deteriorating extent), besides, give different practical solutions to resolve these problems in simple and economic ways[24]. The samples were observed, analyzed, and studied with different investigative and analytical methods: **The Digital Optical Microscope** to investigate the outer surface of the affected ceramic artifacts**, The Scanning Electron Microscope equipped with the Energy Dispersive system (SEM-EDX)** to state the affected surface, and the structure of ceramic samples **-** (SEM Model Quanta 250 FEG (Field Emission Gun).

[23] Corradi, A., et al., *Ancient glass deterioration in mosaics of Pompeii*, article in surface engineering, 2005, Vol. 21, No. 5-6, October, pp. 402-405.

[24] White, Harriet, et al., *Archaeological and Historic Pottery Production Sites*, Guidelines for Best Practice, Historic England publications, 2015, p. 7, 25.

X-Ray Diffraction (XRD) to determine the samples' mineral composition and crystalline phases. In addition to **using Differential Thermal Analysis (DTA)** to recognize the approximate firing temperature. The ceramic samples were sectioned and polished to a 0.1 mm grid before the analyses were performed.

2.1 Digital Optical Microscope;

Digital Optical Microscope was used to investigate the surface of three studied ceramic samples with uncrossed Nichols and b-crossed Nichols filters in magnification resolution (X 200-500).

-The **First sample in dark brown color (Matria store)** remains with traces of a white slip layer on its surface. Moreover, clear-flaked chips appear on the surface and are degraded; there is a high percentage of organic additives in big and clear grains like chopped straw, and the sample has a coarse texture. A thin layer of salt efflorescence also appears in the sample **(Fig. 13a, b, c)**.

-The **Second sample in a light gray color (Fustat store area)** has a thin layer of green glaze on two both surfaces; the glaze is clearly scratched and flaked off, that return to bad store condition and worse handling, and it has a fine texture **(Fig. 14a, b, c)**.

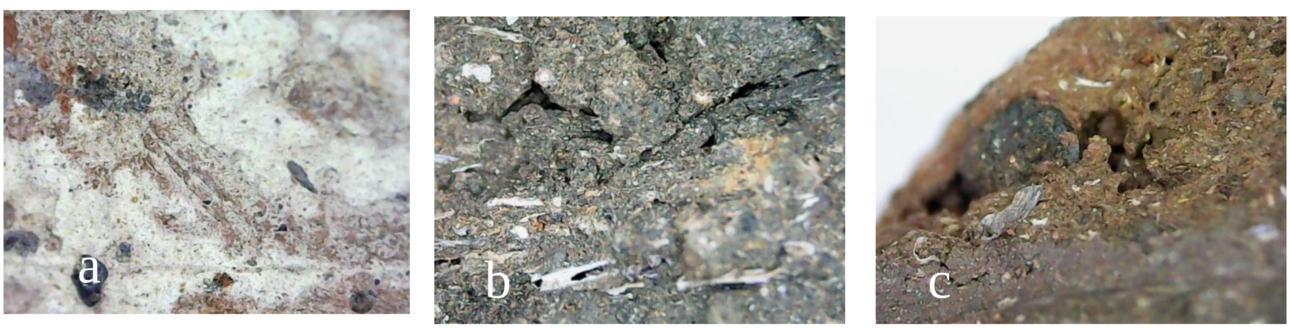

Fig. 13a, b, c

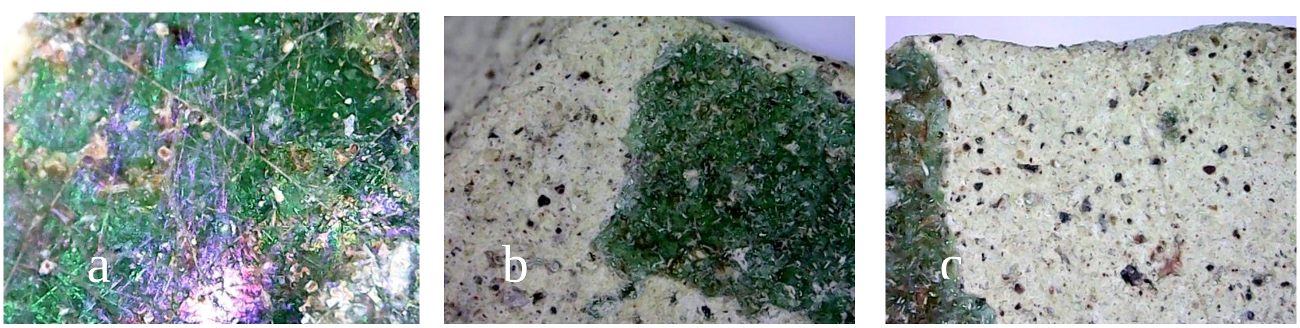

Fig. 14a, b, c

-The **Third sample in brown color (Helwan store)** appears to have inhomogeneity components, and there are variable additive materials in differing grain sizes. The sample is covered with an off-white slip layer on both surfaces (traces of orange color on one side of the slip), and it has a medium texture **(Fig. 15a, b, c)**.

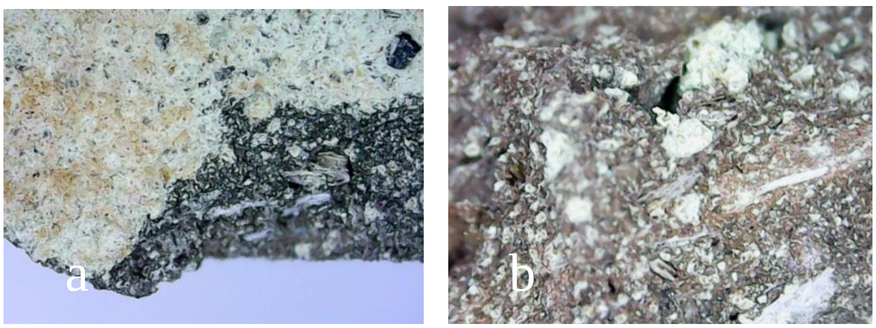

Fig. 15a, b

Fig. (13a, b, c- 14a, b, c- 15a, b) Shows the surfaces, the glaze, the slip, the organic additives, and the texture of the three studied ceramic samples by **Digital Optical Microscope, in magnification resolution (X 200-500)**.

Digital Optical Microscope gave a database to the studied deteriorated ceramic samples based on classification by the clay color after firing, and the different additives, which add to it during the manufacturing process, characterization, and evaluation of their deterioration, have been constructed[25, 26].

2.2 Scanning Electron Microscope equipped with the Energy Dispersive X-Ray (SEM-EDX) system;

That SEM Model Quanta 250 FEG (Field Emission Gun) attached with EDX unit (Energy Dispersive X-ray analyses), with accelerating voltage 30 K.V. magnification14x up to 1000000 and resolution for Gun.1n). (SEM-EDX) investigated the samples' surfaces, also appears micromorphological, microstructural characteristics, and microchemical analyses of surface details. In addition, Scanning Electron Microscope (SEM) equipped with a microprobe (EDX) detects different components like organic additives[27, 28, 29].

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[25] Corradi, *Ancient glass deterioration in mosaics of Pompeii*, pp. 402-405.
[26] Gualtieri, Sabrina & Macchiarola, M., *Ceramics, Mosaic and mortars in the cultural heritage*: Archaeometry and diagnostics. Contact people © Copyright CNR-ISTEC, 2011.
[27] Gualtieri, *Ceramics, Mosaic and mortars in the cultural heritage*.
[28] Santacreu, Daniel, Albero, *Firing Process- 12*, Materiality Techniques & Society in Pottery Production, Unauthenticated, 2014, pp. 87-108.
[29] White, *Archaeological and Historic Pottery Production Sites*, p. 4, 29.

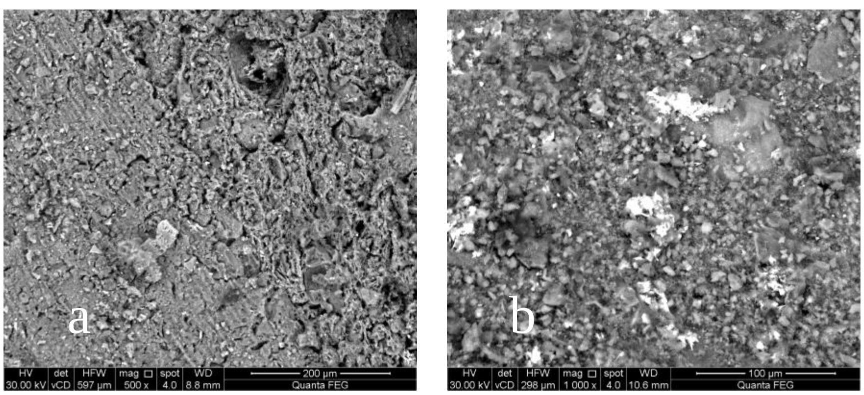
By investigating the three studied ceramic samples in the different magnification resolution ranges in (**Fig. 16a, b- 17a, b, c- 18a, b)**, **It appears that;**

- In the **First sample** returned to **(Matria store)**, the flaked and degraded surface appears, the organic additives in clear and big grains, existing salt efflorescence crystals, and contains a high percentage of quartz as an additive in the texture of the sample. It is high porosity, which means it is a coarse texture and is bad firing, and still contains clay minerals in magnification resolution **(X 500, 1000)**.

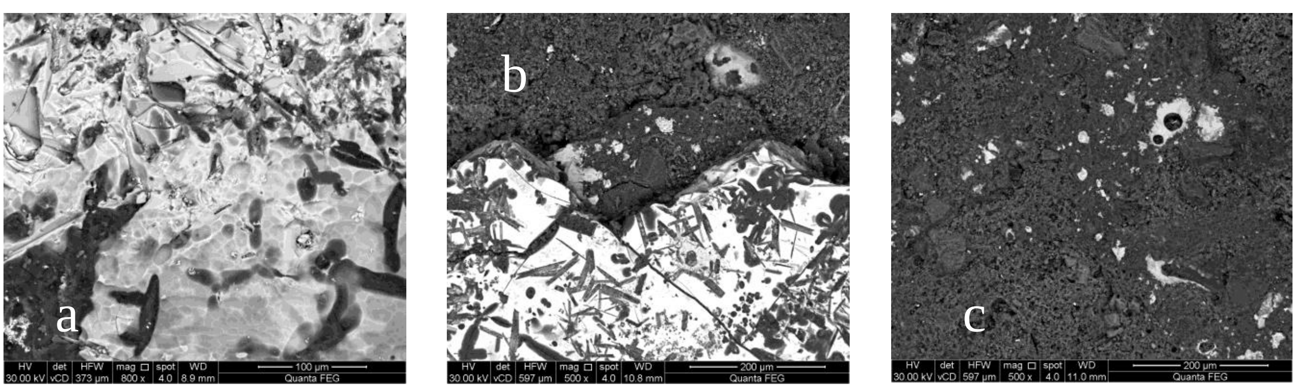
- In the **Second sample** returned to **(Fustat store area)**, it appears the glaze is clearly scratched and flaked off, which results from the bad store condition and worse handle; it notes that the core of the sample is bad firing, in magnification resolution **(X 800, 500, 500)**.

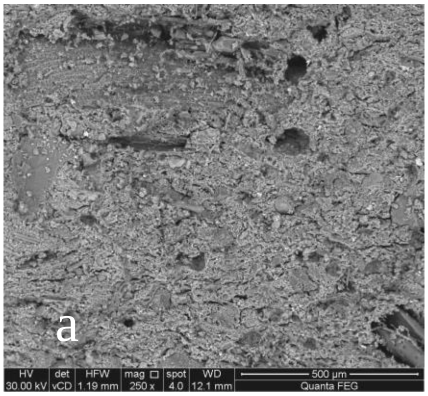
- In the **Third sample** returned to **(Helwan store)**; inhomogeneity components appear in the object matrix. In addition, it is bad firing, and the slip layer is removed from many parts of the sample surface in magnification resolution **(X 250, 500)**.

Fig. 16a, b



17a, b, c





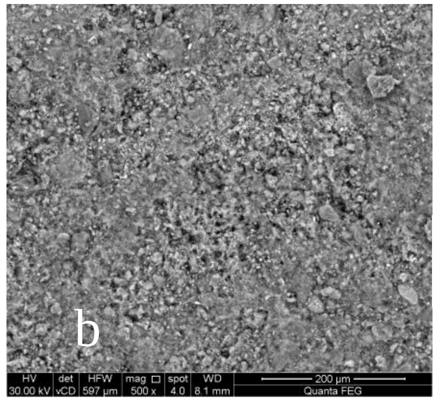


Fig. 18a. b

Fig. (16a, b- 17a, b, c- 18a, b) Shows the surface morphology of the three studied ceramic samples by **(SEM-EDX)**, **with magnification (X 250, 500, 800, 1000)**.

2.3 X-Ray Diffraction (XRD) analysis;

This method is used to recognize the crystalline components in the studied ceramic samples, which give three figures, the first return to **(Matria store)** sample, the second return to **(Fustat store area)** sample, and the third return to **(Helwan store)** sample **(Fig. 19, 20, 21)**.

In Figure 19, the body of the First sample consists of Albite mineral (Sodium aluminium silicate) $NaAlSi_3O_8$ 13.6% – Goethite FeO(OH) as a colorant 12.21% – High percentage of Sand (Quartz) SiO_2 71.1% – also contains a percentage of Halite (Salt of sodium chloride) NaCl of around 3.01%.

In Figure 20, the body of the Second sample consists of Anorthite mineral (Calcium aluminium silicate) $CaAl_2Si_2O_8$ 69.7% – High percentage of Sand (Quartz) SiO_2 25.1% – in addition, a percentage of Halite (Salt of sodium chloride) NaCl 5.1%.

In Figure 21, the body of the Third sample consists of Anorthite mineral (Calcium sodium aluminium silicate) $(Ca,Na)(Si,Al)_4O_8$ 19.6% – Dolomite mineral (Calcium magnesium carbonate) $CaMg(CO_3)_2$ 12.8% – High percentage of Sand (Quartz) SiO_2 52.7% – High percentage of Halite (Salt of sodium chloride) NaCl 19.11%.

All studied Ceramic samples contain a high percentage of Halite (Salt of sodium chloride) NaCl, which salt decays and leads to aesthetic damage through the formation of efflorescence, and physical damage, like micro-cracks, especially in the presence of relative humidity.

The most important results of this study using this analytical method are the presence of clay minerals represented in Albite ($NaAlSi_3O_8$), which absorbs a high percent of H_2O. Moreover, the high percentage of Sand (Quartz) SiO_2 reflects high porosity in the ceramic matrix, making channels that allow water to pass through it. The micro-cracks follow water evaporation and allow propagation of the micro-cracks in the ceramic objects. The use of the analytical method of X-ray diffraction (XRD) also appears the deterioration rate damage by salts in the body, the slip, and the glaze layer.

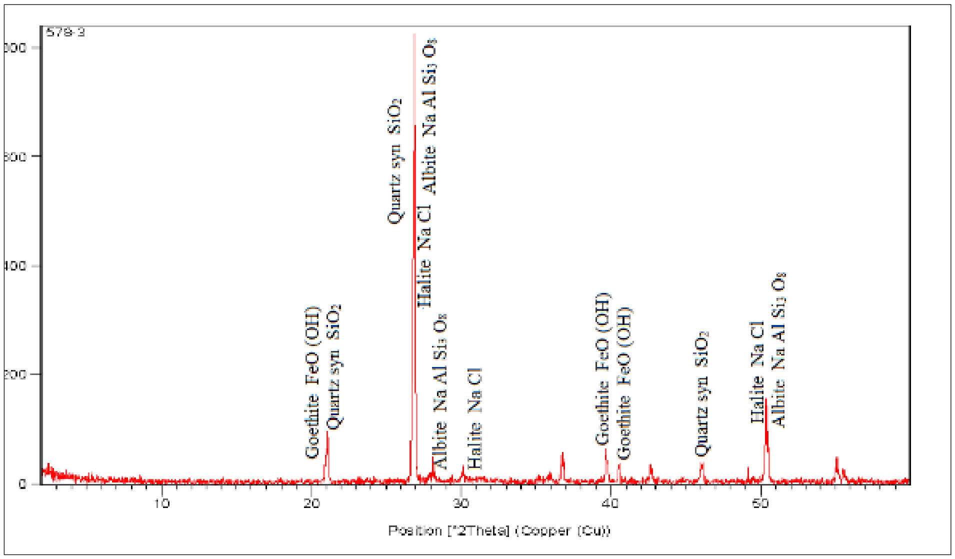


Fig. 19

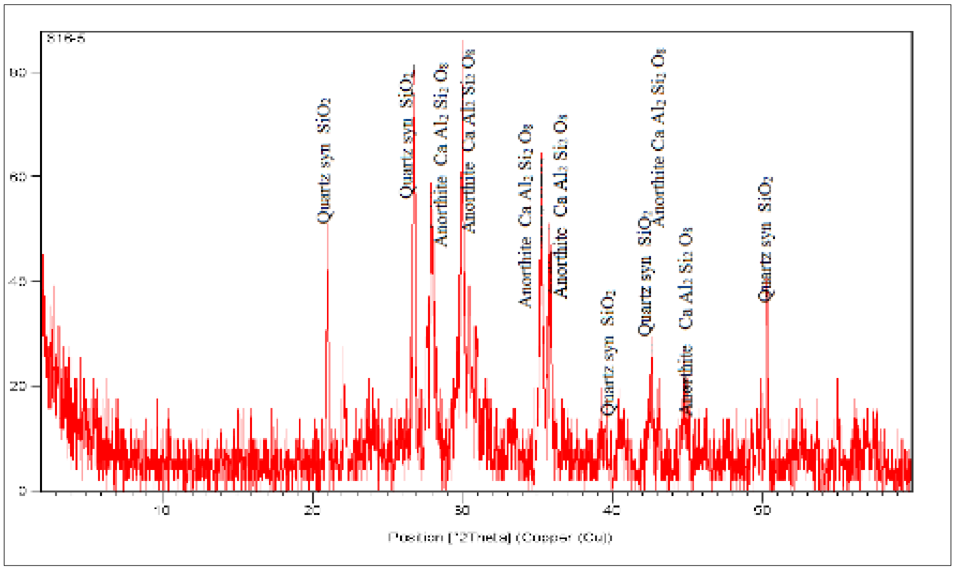


Fig. 20

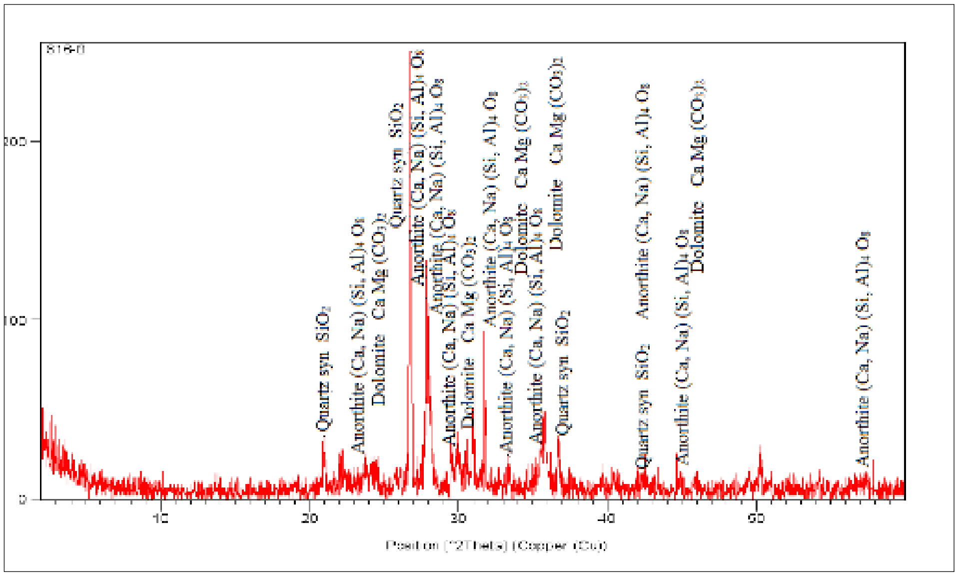


Fig. 21

Fig. 19, 20, 21 Shows the Charts of the three studied ceramic samples from the body matrix and exist of Quartz and Halite in all samples by **(XRD)**.

2.4 Differential Thermal Analysis (DTA);

Differential Thermal Analysis **(DTA)** has a strong relationship with the changes that occurred to the clay matrix throughout the fire process; the formation of the hydrated phases can be monitored[30] as, in good firing, constitutional water is removed from the clay minerals, elasticity and shrinkage are considerably reduced. Then a permanent bonding occurs between the clay particles, so it becomes an impermeable material with certain mechanical properties, suitable for various uses. Just this stage is reached; water cannot be reintroduced to the molecular structure of clay minerals[31]. However, the deterioration occurs when the firing temperature is low because the object still contains partially turned clay phases[32].

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[30] Karatasios, Ioannis, et al., *The second life of Ceramics: a new home in a lime environment*, In: M Martinón-Torres (Ed.), 2014, pp. 271-279.
[31] Danielle, Raad, et al., *Testing a Novel Method to Identify Salt Production Pottery via Release and Detection of Chloride Ions*, Journal of Archaeological Science, 2014, 43 (March): pp. 186-191.
[32] Santacreu, *Firing Process- 12*, 2014, pp. 87-108.

Thus, from the relation between decomposition degree and component stability **(Figures 22, 23, 24)**, we reached that;

- **First Ceramic object** is fired around **(700-750˚C)** and badly fired **(Fig. 22)** and; is strongly affected by bad storing and storage conditions, especially with a high percentage of organic materials it contains, combined with high relative humidity.

- **Second Ceramic object** is fired between **(850-900˚C)** and well-fired **(Fig. 23)**, but it is extremely affected by worse handling, unideal stores, and storage conditions.

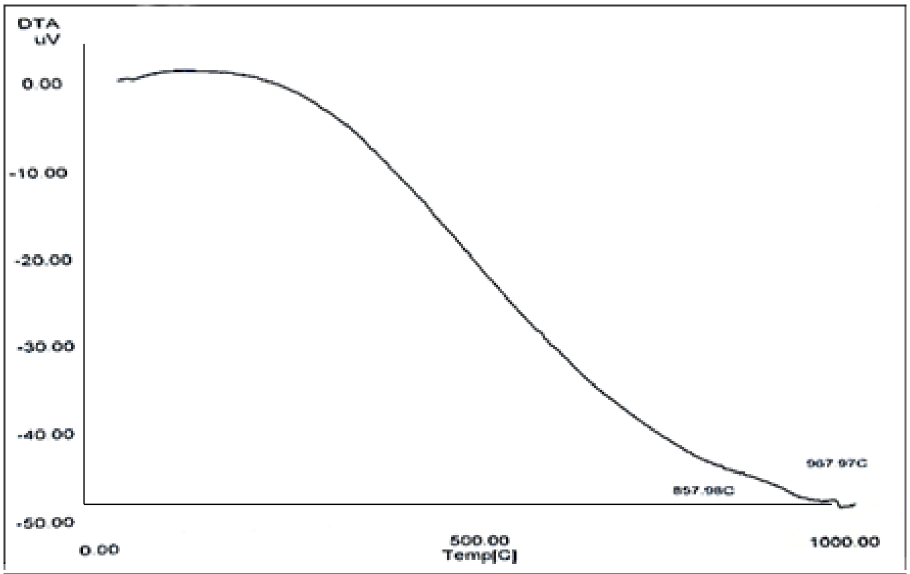

Fig. 22

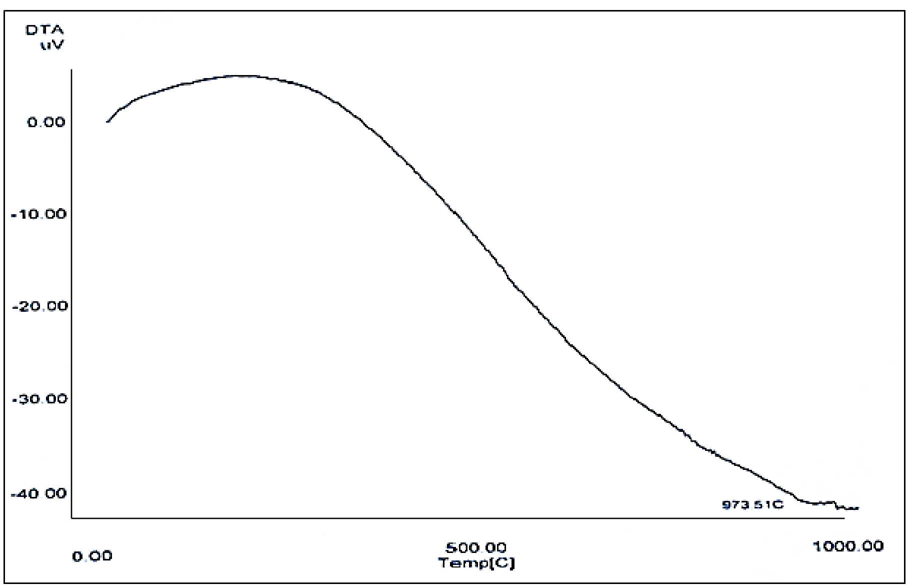

Fig. 23

- **Third Ceramic object** is fired around **(800-900˚C)**, because of the decomposition of Dolomite (Calcium magnesium carbonate) $CaMg(CO_3)_2$, which it contains. Hence, it is good-fired **(Fig. 24)**. It is very affected by bad stores and storage conditions, especially with a high percentage of organic materials, accompanied by high relative humidity.

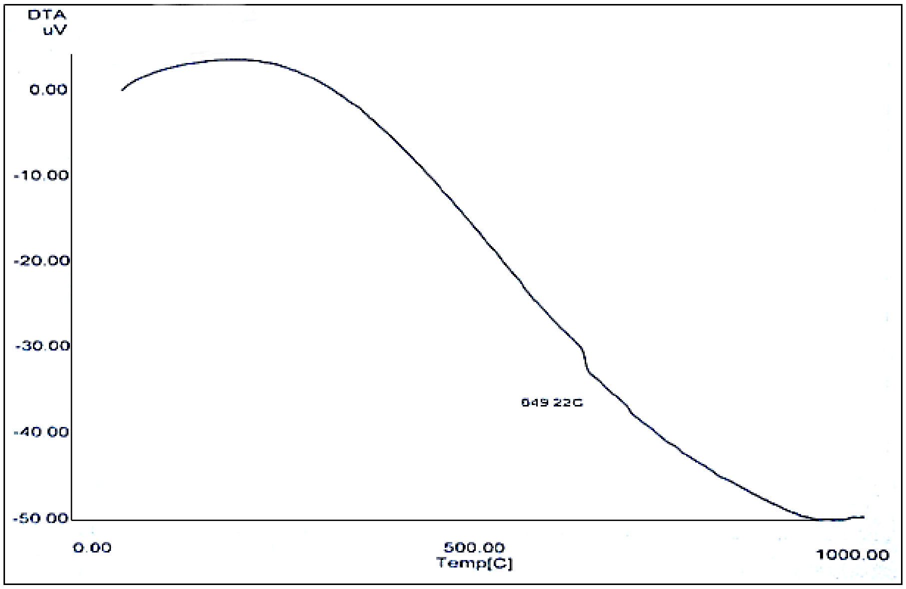

Fig. 24

Fig. 22, 23, 24 The Charts of the three studied ceramic samples from the body matrix show the almost firing temperature, ranging between **(700-900˚C)** by **(DTA)**.

3. Results & discussion

3.1 Results & discussion

- Three small samples representative of deteriorated archaeological ceramics artifacts were chosen from three different storage areas **(Matria store, Fustat store area, and Helwan store)**; archaeological ceramics artifacts are subjected to many deterioration factors; storage is harmful one of these. Especially when the object's texture contains many bores, the surface is fragile and unstable, or it contains a high percentage of organic materials, the extent of deterioration becomes wide.

- In addition to discovering ceramic objects from the ground, which were exposed to dry air after excavation, the soluble salt came to the surface and crystalline there. Later that will appear in the form of flakes - crakes - crystallization in pores - abrasion.

- The ceramic samples, which did not complete loss of chemically bonded water during the firing process, act as a very weak point to salt and moisture deterioration, especially in high relative humidity store places.

- The glaze applied on low-fired ceramics - as in the Second studied sample - means that the glaze can chip off the ceramic body since it is not chemically bound to the body.

- Surface treatment techniques like (painting, luster, burnishing, glazes, slip, etc.), and the position of the object record the state and extent of the object deterioration, whether it covers the entire surface or only a small portion of it.

3.2 Some Practical Solutions

The safe storage of ceramic objects, consolidation, and guarding prefer to happen on the site to reduce the rates of deterioration. For the purpose of excavation and conservation aims, it must begin the steps in the moments after excavation to decrease the damage problems. Good conservation needs communication/relation/between archaeologists, conservators, curators, architects, and other specific[33]. **Sease, C., 1994**[34] emphasizes that the encrustation must be removed rapidly after excavation because that is the first step to treatment and because this encrustation does not turn into another dangerous phase[35]. In addition[36] says that Calcium acetate efflorescence can be consist on ceramic objects in the environment of Museums (in-store places or in displaying hall); it can be removed by using paper pulp, Laponite RD, or Sepiolite packs for desalination. The chloride concentration measured in the solution, and used to quantify the amount of salt associated with the ceramic matrix. In addition, choose an appropriate method to remove it[37]. During the cleaning method, it must avoid scratching the surface. The rough or porous surface is more difficult to clean[38, 39]. Moreover, all excavation objects need continuous conservation [40].

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[33] Guichen, *Object interred*, Object disinterred, pp. 21-28.
[34] Sease, Catherine, *Conservation manual for the field Archaeologist*, Cotsen Institute of Archaeology Press, 3rd edition, California, 1994, p. 22, 26, 29, 80.
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There are different methods to isolate beneath the storage area's wall, including the subsurface drain, by using steel pegs (dowels or pins), or by concrete ribbed or cemented posts or bars[41] **(Fig. 25, 26, 27)**, and there are variable packing materials suitable for small ceramic objects, left to right: PE Zip-lock bag, PE netting, and PP/PE Geotextile fabric[42].

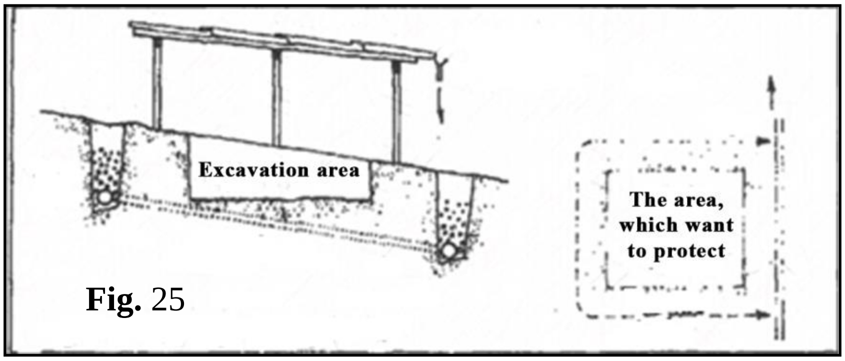

Fig. 25

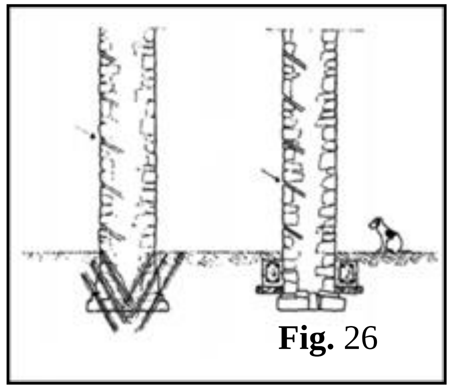

Fig. 26

Fig. 25, 26 Showing from left to right different methods to isolate under the excavation area and the walls of the storage area by the subsurface drain or by using left to right steel pegs (dowels or pins), or by concrete ribbed or cemented posts or bars.
After: **Berducou, M., (2002)**[43].

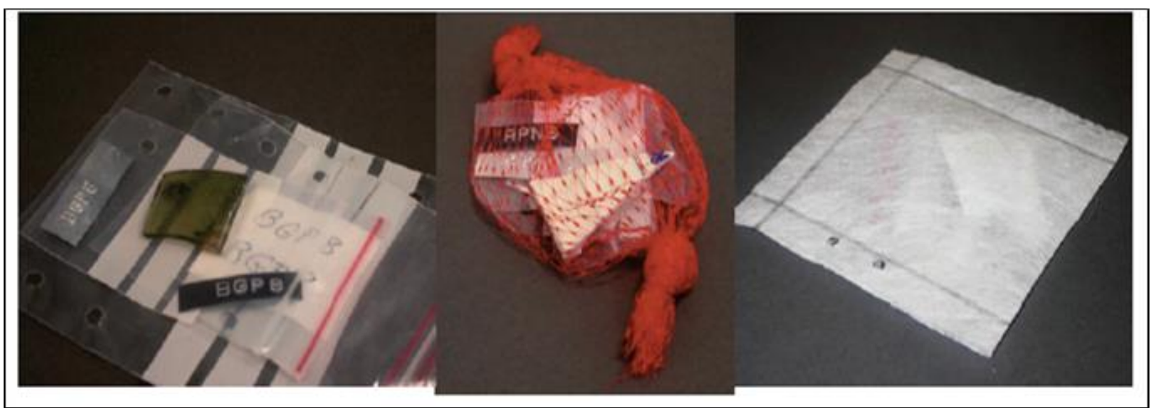

Fig. 27 The variable packing materials suitable for small ceramic objects, left to right: PE Zip-lock bag, PE netting, and PP/PE geotextile fabric.
After: **Bergstrand, Th., Godfrey, I., N., (2006)**[44].

[41] Berducou, *Preservation in Archaeological Science*, p. 498.
[42] Bergstrand, Thomas, Godfrey, Inger, Nystrom, *Reburial and analysis of archaeological remains*, Studies on the effect of reburial on archaeological materials performed in Marstrand, Sweden 2002-2005, Bohusläns Museum och Författarna, 2006, pp. 252-255.
[43] Berducou, *Preservation in Archaeological Science*, p. 499, 510.
[44] Bergstrand, *Reburial and analysis of archaeological remains*, pp. 252-255.

There are different simple methods to control the RH level inside the store places, like, for example, using tight plastic boxes - RH measuring tape, or putting large amounts of Silica gel plastic pages according to the store distance **(Fig. 28, 29, 30)**, besides various RH sensor types **(Fig. 31**). To the left a diagram to compare between sorption curves to different kinds of natural and synthetic padding materials like Konter wood - Pine wood - Carton - Paper, Cotton - Polystyrene, explain the relationship between the rate of RH against equanimity to the rate of RH **(Fig. 32, 33)**. In addition, to the right, variable types of shock absorbance consist of Rubber foam, Micro grains, and Revelations-spring[45]. One of the simple ways recommended for arranging and storing different sizes of ceramic objects is shown in **Figure 34**.

Fig. 28, 29, 30 Showing simple methods to control RH levels inside the store places, by using tight plastic boxes - RH measuring tape, or putting a large amount of silica gel plastic pages according to the store distance; **Fig. 31** Various RH sensor types.
After: **Rimmer, M., (2013)**[46].

[45] Rimmer, Melanie, et al., *Guidelines for the storage and display of archaeological metalwork*, Guidelines, London: English Heritage, Helen, 2013, p. 17, 18, 19.
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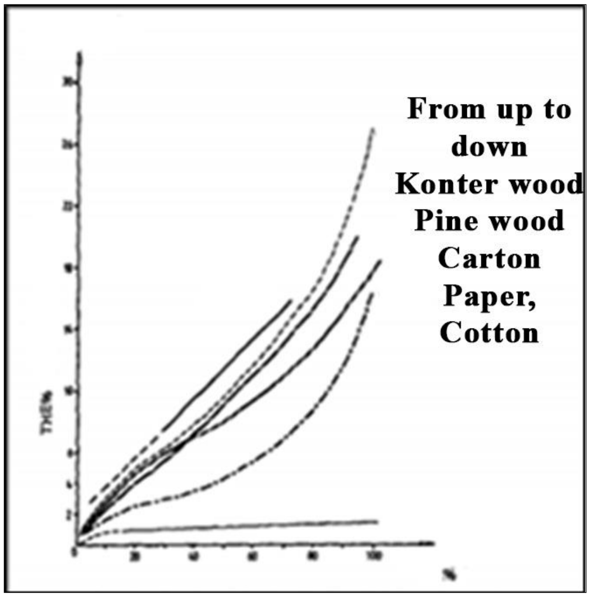

Fig. 32

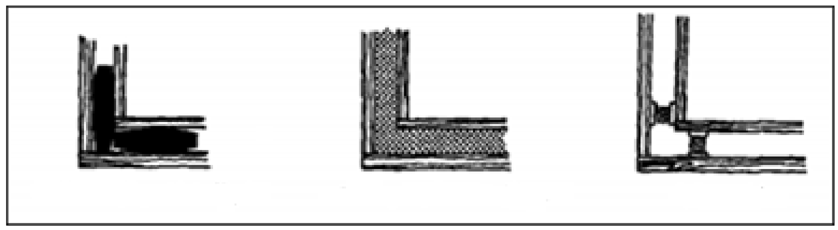

Fig. 33

Fig. 32, 33 to the left, a diagram compares sorption curves to different kinds of natural and synthetic padding materials to the rate of RH; to the right, a variable type of shock absorbance consists of rubber foam, micro grains, and revelations-spring. After: **Berducou, M., (2002)**[47].

Fig. 34 One of the simple methods to arrange and store different sizes of ceramic objects, After: **White, H., et al., (2015)**[48].

[47] Berducou, *Preservation in Archaeological Science*, p. 547.
[48] White, Harriet, et al., *Archaeological and Historic Pottery Production Sites*, p. 12.

4. Conclusion

Three small samples representative of deteriorated archaeological ceramics artifacts were chosen from three different storage areas **(Matria store, Fustat store area, and Helwan store)**. It seems that the transport and storage of ceramic objects should be entrusted only to the project staff or to professional transporters skilled in the movement of fragile objects. Typically, ensure that specialist scientific analysts follow recognized standards of care for objects.

The method of storage and transportation **should be safe - simple, and smart**. During the artifacts transfer to the stores, after detection without a good note of the problems, they are the nucleus of damage after that. It is important to establish repair laboratories and warehouses equipped with scientific methods in the transfer and documentation.

Safety procedures and storage supplies and equipment **are recommended**, like the techniques of lifting, cleaning, consolidating, marking, and storing. In addition, the side effects of ceramic objects were discussed, as well as some practical solutions to solve this problem. Good procedures have resulted in good agreement of results when applied to different ceramic objects in different stores.

The chemical, physical and structural characterization of the Archaeological fragile ceramics were affected during long-term burial in the soil. Then fault storage or transportation, which recognize by analytical techniques. In addition, from noticed many examples and cases in stores that are affected so much by bad storage circumstances and the external deterioration factors around it like temperature, relative humidity, pollution, and acidity; according to the result of **a Digital Optical Microscope**, **The Scanning Electron Microscope equipped with the Energy Dispersive system (SEM-EDX)**. **X-Ray Diffraction (XRD), in** addition **to Differential Thermal Analysis (DTA)**. The restorer can use the effective and low-cost procedure for the storage of ceramic objects in storage areas and units of excavated ceramic.

5. Acknowledgment

I would like to thank everyone who works in archaeological storage sites. Moreover, who tries to improve archaeological artifact's storage circumstances in a case of limited possibilities and at low costs.

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