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The environmental factors affecting the archaeological buildings in Egypt, "II Deterioration by severe human activities"

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ABSTRACT

This paper is the second in a series that addresses the environmental factors affecting the archaeological buildings in Egypt. It presents the results of scientific studies and examinations carried out on one of the most severe deterioration factors affecting the monumental buildings in *a crowded and populated environment (Esna Temple)*. This temple was built during the reign of Ptolemy V (205-180 BC) to memorialize the god Khnum "the holy local god" using Nubian sandstone. In order to understand the effects of a populated environment on this material, samples of sandstone from the temple were examined using some analytical techniques, i.e., XRF, XRD, AAS, PL, and SEM. The results revealed that the temple's constituents include quartz as an essential component of sandstone, whereas the resulting weathering products are halite, anhydrite, niter, sylvite, and kaolinite. They resulted from numerous deterioration factors and relevant mechanisms because of human activities, including aggressive effects of ground and domestic wastewater, as well as deliberate and undeliberate damage. Moreover, vandalism, theft, looting, improper conservation, and other extrinsic and intrinsic factors, especially the alternative cycles between drying and wetting play a role in deterioration.

Keywords: human activities; deliberate; vandalism; theftting; looting; domestic wastewater.

INTRODUCTION

Many of the heritage sites and monumental buildings around the world are vulnerable to several impacts of environmental disasters as *an ascertained danger* (Nicu, 2017) and human hazards as *a potential danger* (World Heritage Committee, 2009). The possible risks related to man-made and natural disasters have been evaluated and predicted to realize damage maps in considerations for the possible deterioration phenomena linked to slow changes (Lazzari et al., 2006; Bonazza et al., 2018). From a specialized point of view, these risks resulted from human activities, such as war (Teijgeler, 2006), despoliation, vandalism (Kuzucuoglu, 2009), urbanization, encroachment, unsustainable tourism, negligence, vibration, etc. In Egypt, there are many archaeological sites and Pharaonic temples in the southern part, especially Luxor, Qena, Esna, and Aswan. These buildings mostly suffer from different deterioration factors that may cause complete destruction (Yocom, 1958; Moncmanová, 2007). Such deterioration phenomena began from the moment they were quarried due to the natural weathering (Winkler, 1996; Webster and May, 2006) caused by physical, chemical, and biological factors (Marey et al., 2010; Daly, 2011; Quinn et al., 2014). The relative importance of each factor depends, on one hand, on the dominated environmental conditions, e.g. the stone type, location on the monument, and preservation state (James, 1980; Papida et al., 2000). On the other hand, the climate-related deteriorations result from temperature variations between day-night and summer-winter (El-Gohary, 2010), water movement within the pores due to capillarity (Borrelli, 1999), etching effects of rainwater, particles carried by wind erosion (Yaldiz, 2010), and some pollutants that affect the groundwater characteristics. Similarly, other factors, such as the crystallization of soluble salts, air pollution (El-Gohary, 2008), biological colonization (Geweely and Afifi, 2011), soot, drops of bat blood (Abd El-Aal, 2012), and wild bee nests (Sleater, 1973) cause deterioration. In addition, shallow groundwater is a major factor in the deterioration of the Pharaonic monuments in Egypt (Campos, 2009). Deterioration phenomena resulting from human activities are the most effective forces of the archaeological sites and Pharaonic temples in the southern part of Egypt (Elbeih et al., 2010). These sites and temples are subjected to variable deterioration factors and related to their mechanisms attributed to human activities (Abdalla et al., 2016). They include four major mechanisms, namely the effects of *ground waters*, *deliberate damage*, *undeliberate damage*, and *improper conservation works*. The present paper provides a brief overview of the destructive processes that result from severe human activities and cause alteration or loss of the archaeological features in Esna Temple (El-Gohary, 2000).

Historical background to Esna temple

The Temple was built in Esna Town (Figure 1a) that lies in (25°18′N, 32°33′E). This town is known as *Ta-Senet* in the Ancient Egyptian Language, *Latopolis* in Greek*, Sne* in Coptic, and *Esna* in Arabic (Wilkinson, 2000). The town is located on the west bank of the Nile River, about 60 km to the south of Luxor. Approaching its temple, a visitor first perceives the roof because the temple still stands on the original ground level, although the modern town rises 9 m higher on top of the remains of the ancient town and its descendants, which grew up around the temple over the last 2,000 years (Bunson, 2002). The temple (Figure 1b) was built during the reign of Ptolemy V (205-180 BC) (Arnold, 1999) to memorialize the god *Khnum* (Montet, 1961) “the holy local god” (Figure 1c). It was built using Nubian sandstone (Klemm and Klemm, 2001) characterized by better external features and internal characteristics compared with other types of sandstones (El-Gohary, 2013).

Environmental status in the study area

Some affecting parameters are directly related to human activities. They play important roles in the accuracy of deterioration cycles around the temple site and facilitate the effects of other degradation mechanisms. They include the meteorological conditions, geological features, topographical features, hydrological system, and stratigraphic scheme.

Meteorological conditions

The study area is located in dry climatic conditions that are characterized by long hot summers and short warm winters (Basheer, Mosaad, 2018). It is one of the most effective environmental factors in the deterioration of the temple’s building materials, especially the porous ones (Riganti et al., 1993; Gimez Moral, 1994). In addition, the area belongs to the continental semi-aired zone that was influenced by hotness and orbital currents and was

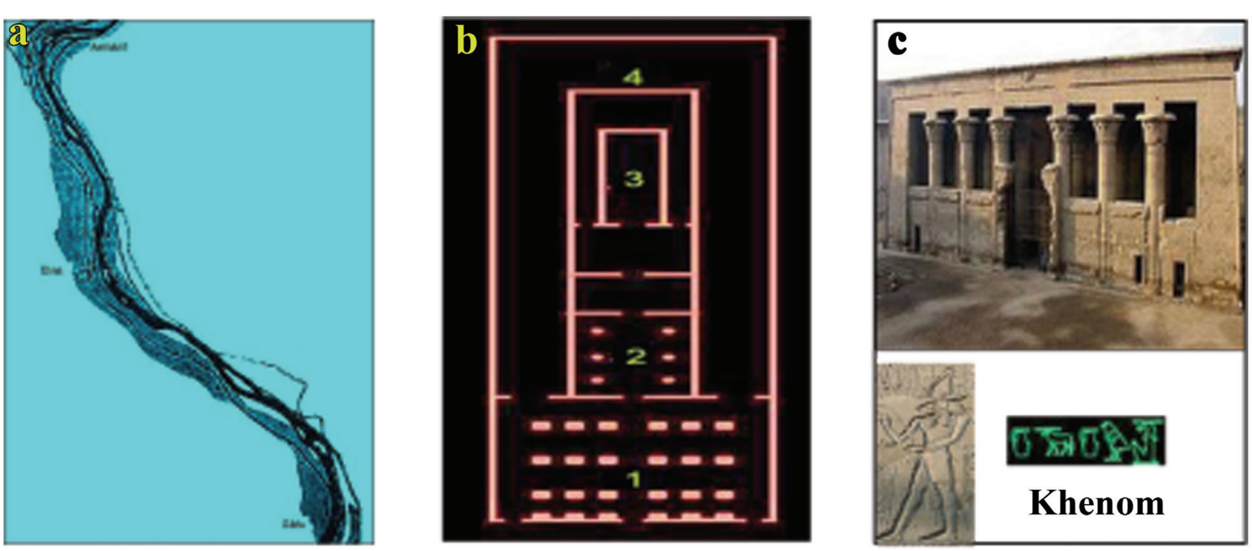


Figure 1. a) Esna town, b) Esna temple (1- Hypostyle hall, 2- Hypostyle chamber, 3- Sanctuary, 4- Gallery), c) Khenom “holy local god of the region.

characterized by a wide range of annual temperature degrees; summer is likely to be extremely hot and winter is extremely cold (El-Bayomi, 2007). Moreover, the two most important meteorological conditions data (AT and RH) were collected over the last 50 years (EMO, 2000). They were classified seasonally as listed in Table 1. The data illustrate that these conditions play an important role in the deterioration cycles affecting the study area, especially through alternative mechanisms between hot (dry) and cold (snowy) (Akmeşe et al., 2019).

Geological and topographical features

Esna (Figure 2a) is one of the ancient Egyptian regions that belong to one of the major Egyptian geological structures; it is a stable shelf (Awad et al., 1963). This area is a part of a strap surrounded by unknown borders composed of Nubia stone (Pettijohn, 1983; El-Gohary, 2013), and continental and semi-continental sediments from the Late Cretaceous and the Early Tertiary (Singer and Amiel, 1974). The Temple is 180 m from the west bank of the Nile River; about 8.80m below street level. It is encompassed by recent houses and other civil and religious buildings (Figure 2 b,c).

Hydrological system and stratigraphic scheme

The study area is highly influenced by the Nile water flow because of the direct hydraulic connection between the Nile River and the quaternary system in the Nile Valley (El-Fakharany and Fekry, 2014). This effect may be due to groundwater flow, which is primarily toward the river from the valley walls, with a slight northward (downriver) gradient present (Brikowski and Faid, 2006). Also, it may be attributed to the high index of hydraulic conductivity characterizing the bedrocks of the area, including dense stone materials “*sandstone and limestone*” (El-Gohary, 1996) or the low index of hydraulic conductivity characterizing the soil of the area, including clay and pebble materials “*gravel and silt*” (Figure 3a). The hydrological studies done to evaluate the quantity and quality of the water well within the temple and other wells in the surrounding area revealed many points. The 1st point is that the Nile mostly charges the wells both in and around the temple, which attests the hydraulic conductivity (0.016 mm/m) from the Nile to the wells (Figure 3b). The 2nd one shows that the temple’s building materials are an easy target for the physical and chemical attacks due to the eccentric site of the temple

Table 1. Seasonal average of meteorological elements of the Esna temple area last 50 years.

Meteorological Elements	Winter			Spring			Summer			Autumn		
	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.
AT ºC	16.6	14.9	16.8	20.9	26.0	30.1	32.4	32.6	32.5	30.4	27.4	21.7
RH %	51	50	42	35	26	23	33	29	30	34	36	46

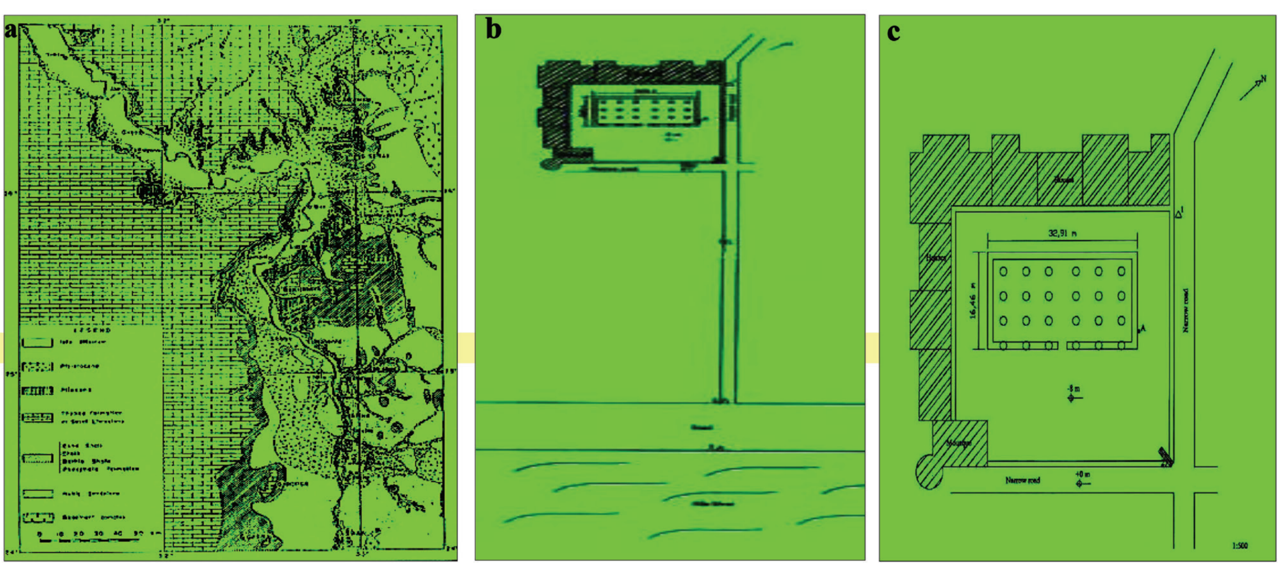


Figure 2. a) Esna temple encompassed from all sides by recent houses and buildings, b) the relation between the temple and the river Nile, c) geological features of Esna area.

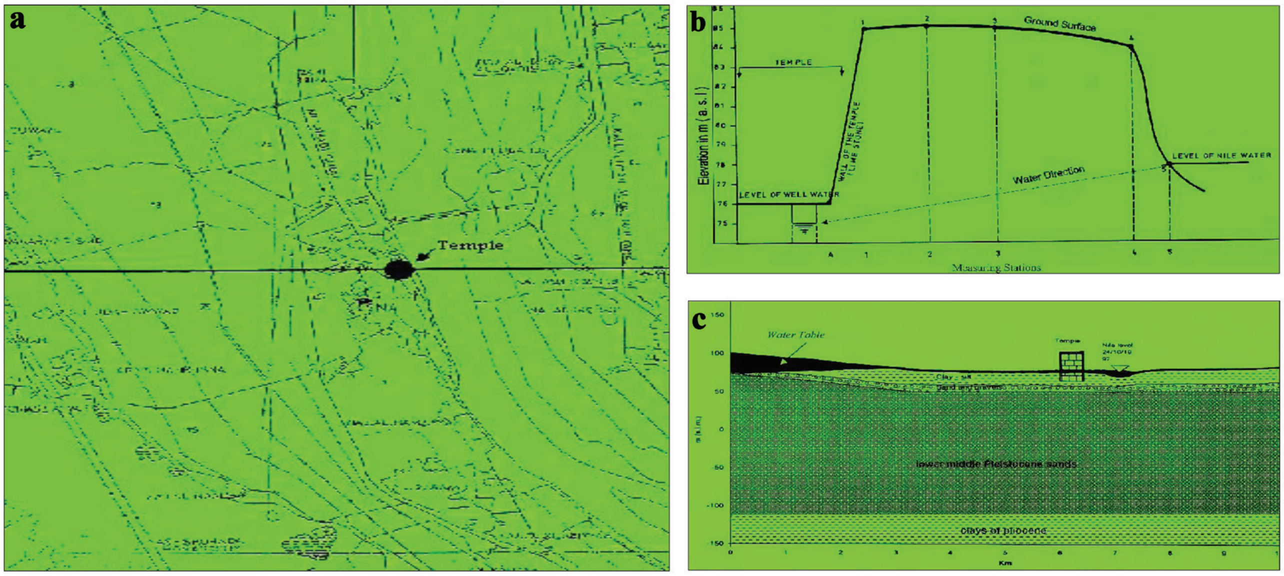


Figure 3. a) topographic features of the Esna temple, b) Hydraulic section in the temple, c) Hydro-stratigraphic system of temple area.

(8.8 m below street level). The 3rd one is that the stratigraphic scheme of the temple area (Figure 3c) composed from Esna shale belonging to the Eocene Epoch (Beadnell, 1905; Said, 1961) is characterized by different features, as listed in Table 2.

Table 2. Stratigraphic scheme of the Esna temple.

Stratigraphic layers	layers
Silt -clay	20-22 m
Sand and gravels	5 m
Lower-Middle Pleistocene sand	200 m
Clay of Pliocene	Un-defined

HUMAN ACTIVITIES, DETERIORATION PROBLEMS, AND RELATED FORMS

The massive investment in protecting the monuments makes it essential to utilize any scientific knowledge of weathering processes (Cardella, 2008). Stone weathering phenomena, resulting in external stress and internal strains, are mostly involved in the deterioration cycle of archaeological buildings and destroy their main materials (Bland, 1998). The temple was highly affected by the successive numerous deterioration factors of human activities, as well as other extrinsic and intrinsic factors (Hoyos et al., 1998; El-Gohary, 2012). Thus, it is important to understand the processes, factors, and mechanisms that are caused by human activities and threaten archaeological buildings. It has been illustrated that drainage water, agricultural drainage water (Cunliffe, 2014) and domestic wastewater (Pulido-Bosch et al., 2018) are the most important sources of groundwater and have affected the temple area (El-Gohary, 1999; El-Gohary, 2000). These water sources cause some physical, chemical, and biological deterioration mechanisms. Moreover, other human activities, i.e. deliberate and undeliberate damage, result in destructive effects. The deliberate damage is intentional and results from direct or deliberate human activities, such as looting (theft) and vandalism. Looting and vandalism remain ongoing problems at archaeological sites in many parts of the world as attested by Kersel, Chesson (2013). They are exacerbated or brought on by the tragic political conflicts (Atwood, 2009), stories of ancient treasures, antiquities trade (Renfrew, 2000; Vella et al., 2015), etc. While the undeliberate damage is mostly unintentional and covers the effects of wars and firing in the aired area, the improper conservation works due to using unsuitable materials, such as black cement and reinforcement concrete, or applying wrong conservation techniques play a role (Urban woodland management guide 1, 2002; Cohan, 2004; Elizabeth, 2008; El-Gohary, 2007). According to Kühlenthal and Fischer (2000) and El-Gohary (2010), the close inspection and complimentary survey (CICS) was adopted to evaluate the structural features and the past evidence of the temple and its surrounding area and to focus on the different deterioration activities. The study revealed that the temple is highly affected by deterioration mechanisms and there are several deterioration forms, such as:

1. The spread of saline groundwater containing different sources of salt below the temple foundations, salt crystallization, collapse of the ground due to losing internal cohesion, and leaching of mortar beds and silica content between stone blocks (Figure 4a).

2. The spread of soot particles and the growth of sulfate-rich crusts on the internal parts of the temples due to cocking and full inhabitation inside the temple, the mechanical destruction due to intentional damage, and the presence of soiling and crusting layers on the stone surface (Figure 4b).

3. The collapse of the sandstone structure due to the disintegration of ferrous cement material resulting from salt crystallization, as well as brittleness and fracture symptoms due to alternative cycles between hydration and crystallization processes (Figure 4c).

4. The destruction of the stone body due to using improper treatment materials in the past such as black cement and other organic materials (*rags*) (Figure 4d).

MATERIALS AND METHODS

From different locations of the temple, 25 structural sandstone samples, weathered surfaces, and mortars were collected. They were targeted to different analytical and investigation techniques to define the deterioration products and their different features. According to De Geyter (1985), Hardy et al. (1989), Rollinson (1993) Hughes et al. (1976), and Fidelibus (1993), these samples were investigated and analyzed using *Leica Polarizing Light Microscope at 50-200x magnification* (PLM). *Shimadzu Lab X, XRD 6000 X-Ray Diffractometer* (XRD) was adapted to define the mineralogical composition of stone samples and their optical characteristics. *The*

Figure 4. Deterioration symptoms affected Esna temple.

Energy-Dispersive X-ray Analyzer EDS INCA300 attached to *a LEO1450VP Scanning Electron Microscope* (SEM-EDS) was utilized to investigate the morphological features of the deteriorated samples and their chemical components. Finally, *Perkin Elmer AAS Analyst 400 Spectrophotometer "Unico-1200"* (AAS) was performed to evaluate the chemical and mineralogical characteristics of the groundwater samples.

RESULTS

The obtained results strongly indicate that the temple site, structure, and different components were highly affected by complex deterioration mechanisms and forms. These results are concluded, as follows:

PLM and XRD results

Petrographic examinations help determine the specific minerals, rock textures, coarseness, as well as relative or quantitative percentage of various constituents (Reedy, 1994). In addition to the identification of the exact typology of the stone, its physicochemical properties and deterioration state are also defined (Corbeil, 2004). XRD measurements and petrographic features of the samples illustrate that the main compositions are divided into two groups. The 1st group includes major minerals [Quartz SiO_2, Halite NaCl, Anhydrite $CaSO_4$ and Niter, KNO_3], while the 2nd group covers minor minerals [Calcite $CaCO_3$, Dolomite CaMg $(CO_3)_2$, Sylvite, KCl, Kaolinite $Al_2Si_2O_5$ $(OH)_4$ and Biotite (Al, Fe) Si_3O_{10} (OH,F)]. These constituents are detritus grains with angular, sub-angular, rounded, and sub-rounded shapes in siliceous and ferrous cement materials (Figure 5 a,b,c).

SEM-EDS results

The morphological examination by SEM reveals that several deterioration symptoms affect the sandstone as a building material that includes the severe etching of quartz grains, the spread of salt crystals in cubic shape (Halite), in addition to the rarity of stone cement material. Moreover, the brittleness and weakness of quartz grains, the presences of some pits stone crumbs, and the granular disintegration result from the effects of saline water (Figure 6 a,b,c). The EDS results suggest that the samples are composed essentially of ideal elemental components characterizing the Egyptian sandstone, where the average elemental ratios are (Si 42.17%, Ca 20%, Cl 15.2%, K 8.3%, Na 5.3%, Fe 4.4%, S 4.3%, then Al 2.5%, in addition to some traces 0.01).

AAS results

Geochemically, groundwater quality was defined using AAS and chemical titration analyses at the Facolty of Ingegneria-Politecnico di Bari, Italy. The analyses attested that TDS has very high values due to the variety of water sources (River Nile, *Rammady canal*, domestic sanitary wastewater of the surrounding houses, and drainage water). Furthermore, water has some characteristics of seawater, as has been argued by Tulipano et al. (1994) and Klark and Fritz (2013). The obtained data are listed in Table 3.

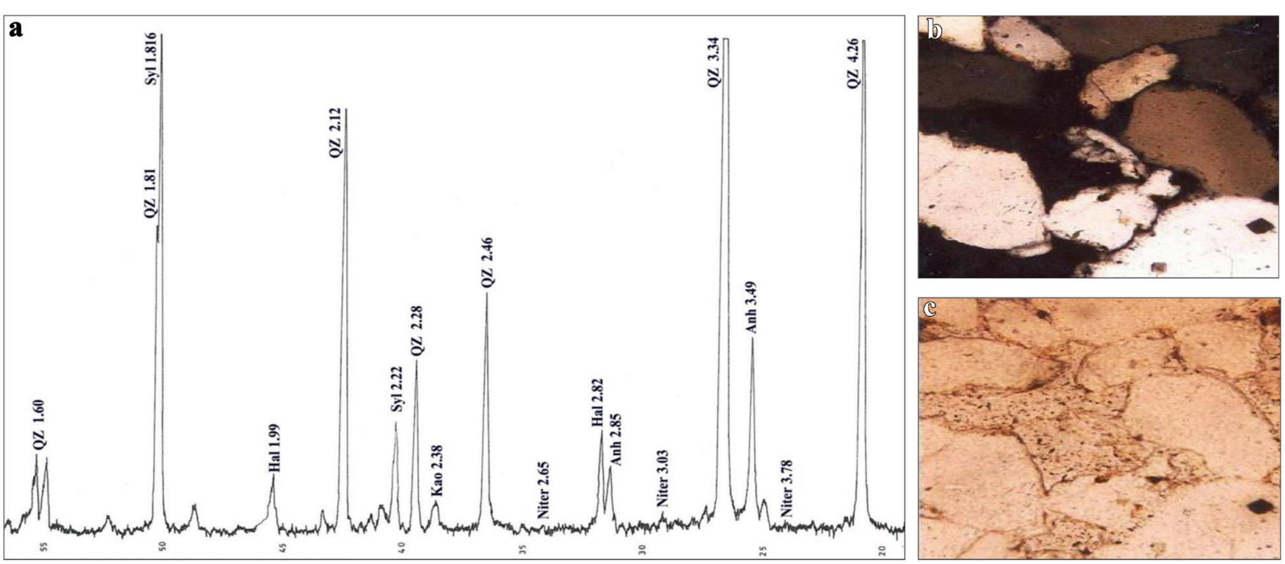


Figure 5. Mineralogical composition of deteriorated samples collected from Esna temple a) by XRD patterns b) by PLM micrographs.

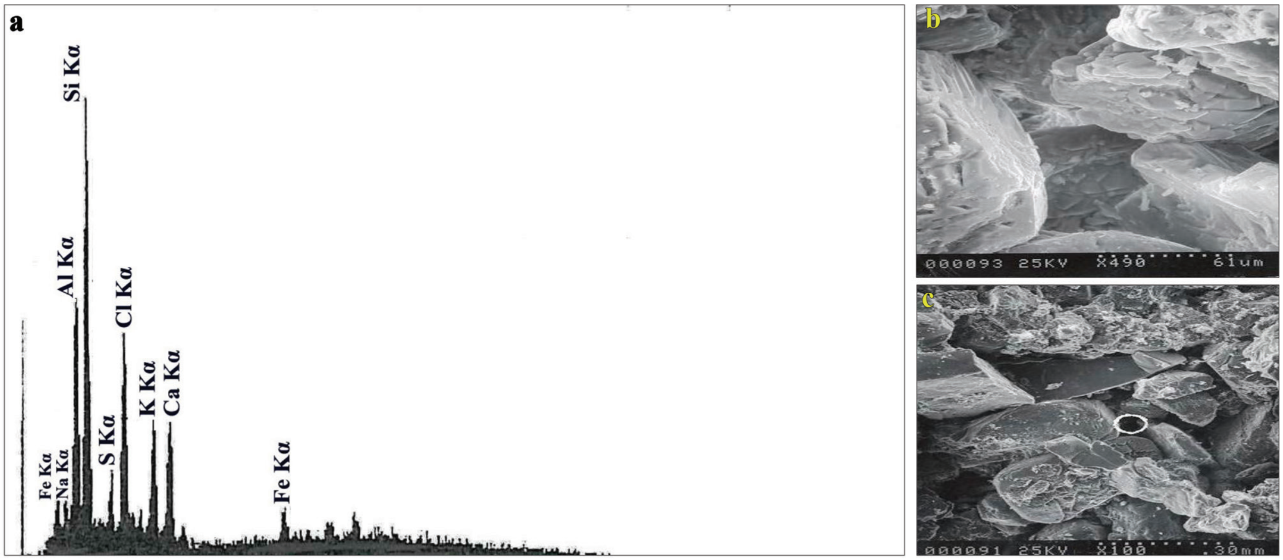


Figure 6. a) EDX patterns b, c) SEM photomicrographs of deteriorated samples collected from Esna temple.

Table 3. Chemical analysis of groundwater of the Esna temple well by AAS.

Cations (mg/l)				Anions (mg/l)				
Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	CO_3^{--}	Cl^{-}	SO_4^{--}	NO_3^{-}
73.5	215.4	1069.6	477.9	454.0	70.8	1136.0	723.9	1413.8
Other Properties								
TDS: 4.2 g/l	pH: 8.7	Hardness: 106.9	EC: 6930	E: -0.25%				

DISCUSSION

The interaction between the deterioration factors affecting the monumental sites was almost cleared and varied according to the dominant environmental conditions. The human actions are the most severe environmental and extrinsic factors that have caused the deterioration of Esna Temple, as illustrated in (Figure 4 a,b,c,d). Although all building materials have a stable environmental state, a significant change in the environment may force the materials to be transformed into others with a new stable state. These processes are known as weathering or deterioration (Camuffo, 1995; Barroso et al., 2006; Mora Navarro et al., 2016; Pozo-Antonio et al., 2018). They are often attributed to different reasons, especially breaking the rules and laws prescribed by some governing authorities (Chakrabarti B. et al., 1996; Elia, 1997; Canti and Linford, 2000; Silva et al., 2005; Daly, 2011; Rodríguez-Pascua et al., 2011). In the case under study, many sources of groundwater have affected the body of the temple, including drainage water, agricultural drainage water, and domestic wastewater (El-Gohary, 2000). Although traditional agriculture is an important economic activity in the study area, the destruction of the archaeological sites is occasionally caused by drainage water as has been discussed in a similar case (Zimmerman et al., 1988). In other words, the agricultural activities cause several deterioration features, in addition to brittleness and fracture symptoms (Halsey, 1996) caused by alternative cycles between hydration and crystallization actions (Vicente et al., 1994) due to the presences of aggressive fertilizer types. Accordingly, it could be said that the types of water are the main factor of deterioration that results from dissolution and ion exchange between the building materials and the dominating salts in water. The alternative cycles between drying and wetting play a role, as well.

Through analyzing the XRD data (Figure 5), it could be asserted that Halite is a ubiquitous soluble salt (Lubelli et al., 2006a) belonging to the chloride species. It is one of the main salts characterizing the bedrock and hole of the Egyptian soil (Gauri and Holdren, 1981; Wüst and Schülchter, 2000). In the study area, halite comes from the domestic water and severely affects the temple’s stones because of the synergetic reaction with other soluble salts. This effect causes the maximum deterioration and corrosion of the stone body, including the presence of the white layers of salt efflorescence, the disintegration of ferrous material, and the surface brittleness (Smith and McGreevy, 1988). Sylvite is ranked second in the chlorides of our case. It is composed through ion exchange between calcite in the water below the temple and potassium nitrate used as a fertilizer in the agriculture activity. It is extremely dangerous because of its high ability to crystallize in hot environments and re-crystallize in humid environments (Amoroso and Fassina, 1983). Moreover, anhydrite is the most important sulfate resulting from the chemical reactions between the aggressive sources of saline water and the different components of the building materials (El-Gohary, 2011). These reactions commonly originate from wet and dry deposition processes in which sulfate products cause the loss of the mass, as well as strength and stone cracking due to expansion and contraction mechanisms (Skoulikidis and Beloyannis, 1984; Charola et al., 2007). The growth of the sulfate-rich crusts on rocks has been explained recently by increased air pollution due to anthropogenic activity (industry, coal burning, urban traffic, etc.) (Siedel and Klemm, 2000). These processes may be attributed to the surface-treated materials. In the same context, the formation of the sulfate-rich exo-crusts on stone surfaces is more likely linked to restoration/conservation steps. This could be explained, on one hand, by mineralogical and chemical homogeneity of sandstone with clay matrix on the broad variability of sulfates in exo-crusts. On the other, the effects of the mineralogical variability of exo-crusts reflect different periods of sculptures' origin and later surface treatments (Přikryl et al., 2004). According to Laue et al. (1996), niter is attributed to the use of nitrates as a fertilizer or the decomposition of organic matters. It normally gives thick efflorescence that is easily eliminated, creating some disintegration actions less than those of sulfates (Feilden, 2003). This salt may have been introduced from external sources, such as rising damp from the soil or through some species of microorganisms and other biological activities (Berry, 1994). It may also result from the bio-deterioration processes originating from the abundant guano deposits (Hernanz et al., 2008). Kaolinite is the most important clay mineral in sedimentary rocks (*1:1, dioctahedral*) (Ruedrich et al., 2011). It is a simple and common aluminosilicate composed of tiny sheets of triclinic crystals with pseudo-hexagonal morphology (József and Williams, 2005). In our case, it acts as a key factor controlling the petrophysical properties of the sandstone (Kassab et al., 2017) and may result from kaolinization due to the effect of hydration and hydrolysis mechanisms (Robertson and Eggleton, 1991; Humble, 2019). These mechanisms are caused by the absorption and chemical reactions affecting different silicate species. As a result, clay minerals swelling are enhanced (Delgado Rodrigues, 1976; Nascimento et al., 1968) depending on the presence of some kinetic factors (e.g., pH, temperature, activation energy, and the degree of saturation) (Helmi, 2000; Metz and Ganor, 2001). All of these salts lead to the degradation of detritus quartz grain "the main component of sandstone", as shown in (Figure 5b), changing their ideal shape from angular and sub-angular grains (77.65% measure 0.095-0.35 mm) to round and sub-round grains (22.34% measure 0.075-0.48 mm). Such changing processes essentially result from different weathering processes, stress, and strain mechanisms (De Geyter, 1985; Appolonia et al., 1985; Queisser et al., 1985). EDS data (Figure 6a) show the main elemental components of minerals obtained data by XRD. That is, Si is the main component of quartz, Ca is the main component of calcite, Na and Cl are the main components of halite, K is the main component of niter and sylvite, Fe is the main component of biotite, S is the main component both of anhydrite, and Al is the main component of kaolinite. They all suggest the presence of other trace minerals, such as dolomite and ferruginous cement. SEM results (Figure 6b) reveal that there are abundant ideal crystalline phases of both quartz grains halite and etched cement materials resulting from the aggressive effects of saline groundwater and other deterioration features, which can be visualized in different images, as has been argued in similar cases (Benavente et al., 2004; Steiger, 2005; Lubelli et al., 2006b). Finally, AAS analytical data (Figure 7) show the soluble salts characterizing the geological structure, water seepage from the surrounding houses, and nearby cultivated lands caused by a high index of saline ions. Subsequently, the deterioration processes become more effective because the TDS of the analyzed sample equals 4.2 g/l, making its chemical characteristics similar to seawater, as discussed by Jakhrani et al. (2012). These characteristics almost cause severe deterioration forms, as argued by El-Gohary (2011, 2012).

Although "groundwater as a human activity" is believed to be the most influential factor in the deterioration of the Esna Temple area, other factors cause more effective deterioration forms, such as vandalism and theft (looting) as deliberate damages, firing as un-deliberate damages, in addition to improper conservation works. *Vandalism* is one of the most critical concerns for land managers and professional archaeologists. It causes the destruction of the vestiges of the nation's historic and prehistoric cultural resources (Nickens et al., 1981; Lahiri, 2001). Vandalism and its resulting damage range from graffiti to the complete destruction of the monuments or even the entire archaeological sites. This act can be opportunistic (unplanned) or premeditated (planned). Thus, it is important to define the type that takes place

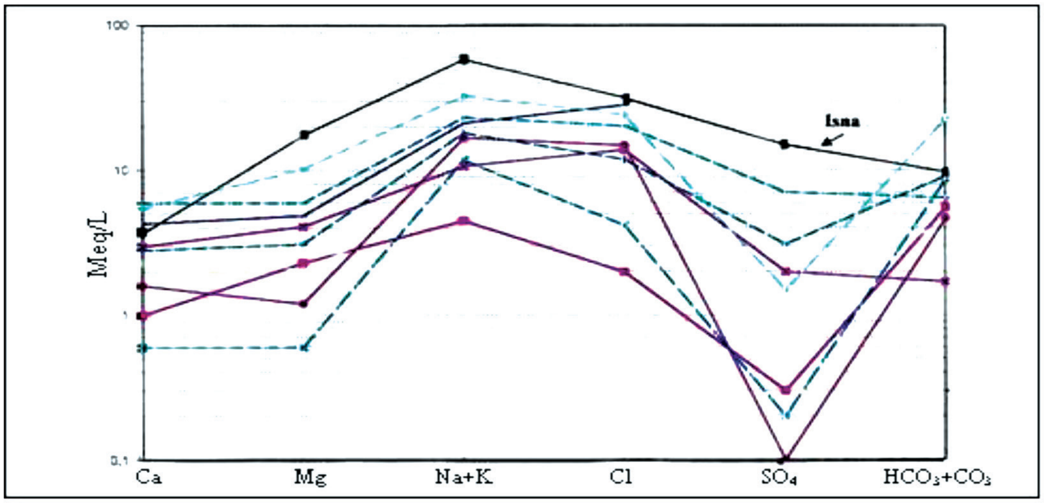
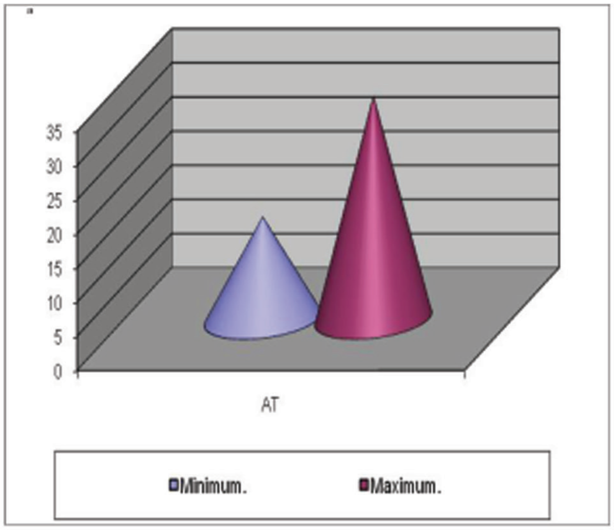


Figure 7. Diagram shows the salty elemental ratios in Esna temple well and other surrounded wells in the area.

on the site (Huges, 1995; Sivan, 1997; Urban woodland management guide 1, 2002). *Theft (looting)* of antiquities and destroying the different important aspects of the nation's cultural heritage may be due to a lack of security. According to numerous reports, the direct damage and breakdown of archaeological sites have increased looting. Looting is either unplanned or planned (Brodie and Renfrew, 2005; Stone, 2008). The archaeological sites are also abused by looters using amateur techniques that destroy or cause the loss of some features. This may be done by looting sites completely and destroying irreplaceable archaeological data (Elizabeth, 2008; Cohan, 2004). *Fire* is one of the primary threats to historic property (Kidd, 1995) that stands out among decay agents because it generates irreversible decay of stone, with long-lasting effects, in a very short time (Gomez-Heras, 2009). It is caused by accident - dropped cigarettes and neglected sites (Bond et al., 2008). According to Stovel (1998), fire may be caused by arson, careless hot working and other building works, kitchen-related accidents, faults in electrical installations, discarded burning cigarette ends, and climate change. In the case study, the fire has mostly affected different internal parts of the temple due to the inhabitation by Christian, especially during the Roman Era in Egypt (Perera N., 2017). These processes cause several deterioration forms, especially the spread of soot particles on the surface due to cocking and full inhabitation inside the temple (Figure 4d) and mechanical destruction due to intentional damages. In addition, soiling and dusting have formed layers of dirt with the presence of RH and affected the entire stone structures (Camuffo, 1995; El-Gohary, 2010). *The improper conservation works* were conducted without considering the code of ethics and the code of practice (El-Gohary, 2007). In addition, the improper selection and use of conservation materials result in different forms of damage, especially salt crystallization, cracking, scaling, and partial loss of mortar and stone (Szemerey-Kiss and Torok, 2017). In the case under study, the old conservation works were done using improper materials, such as black cement as a mortar (Ostrasz, 1997; Meloni et al., 2015) and fragments of red brick and/or rags, as mentioned in (Figure c). In the same context, mineral transformation is another serious symptom that affected some parts of the stones because of improper conservation materials (Emara and Korany, 2016). Their effects resulted essentially from acid rock drainage and contact water (Price and Errington, 1998). This symptom caused swelling of some clay types through expanding their crystal lattice as an intraparticle swelling mechanism, as argued by Delgado and Rodrigues (2001). Finally, all of the previous deterioration symptoms were enhanced by the abnormal variations of the climatic conditions, as listed in Table 1, especially the alternative cycles of drying and wetting, where the minimum degree of AT is constantly in January and the maximum is in July. Furthermore, the minimum degree of RH is almost in December and the maximum is in May (Figure 8).

CONCLUSION

Through the scientific overviews given by the previous investigations, it could be concluded that human activities affecting Esna Temple proved that its building materials were highly affected by many deterioration mechanisms, such as groundwater, deliberate and undeliberate damage, vandalism, theft, and looting. Many deterioration forms are manifested, including the spread of saline groundwater, some salt species, soiling and crusting layers, leaching of mortar beds and silica content, collapse



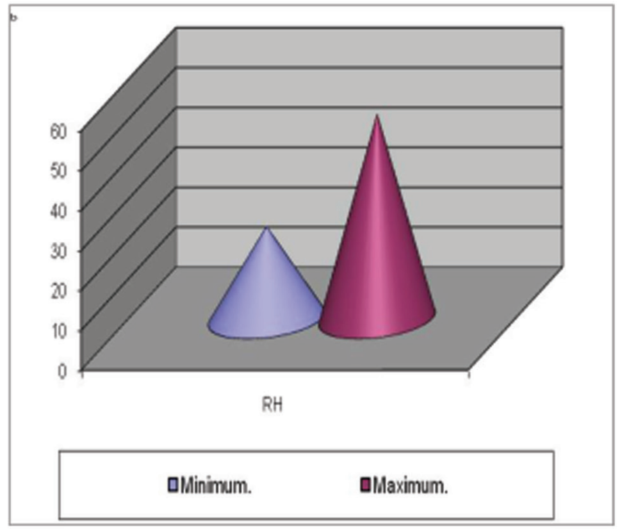


Figure 8. The average of minimum and maximum degrees of a) air temperature, b) relative humidity in the last 50 years in the study area.

of sandstone structure, as well as some brittleness and fracture symptoms. Accordingly, some recommendations are made:

- Catching the looters through national and international efforts, especially by developing the active preservation programs to handle these threats.

- Constructing a drainage system comprising wells and pumps within and around the temple boundary to ensure adequate protection against groundwater.

- Strengthening the building elements and existing masonry constructions using some basic methods, e.g., repairing of cracks, re-pointing the joints with suitable mortars, grouting with modified cement, or epoxy grouts.

- Preserving the different deterioration of the temple's building materials through conservation programs, depending on two essential steps. The 1st step is the actual work and preventive conservation strategy, whereas the 2nd one is conducting a pilot study of the temple's structural conservation.

REFERENCES

Abd El-Aal Sh., 2012. Evaluation of biotechnology in the conservation of wall paintings in the mortuary temple of Ramses III. EJARS 2, 79-89.

Abdalla F., Moubark K., Abdelkareem M., 2016. Impacts of human activities on archeological sites in southern Egypt using remote sensing and field data. Journal of Environmental Science and Management 19, 15-26.

Akmeşe H., Büyükşalvarcı A., Över Z., Aras S., 2019. Cultural heritage of Beysehir from eleventh century until today In: Caring and sharing: The cultural heritage environment as an agent for change. (Ed.): V. Vasile, Springer International Publisher AG, Germany, 379-388.

Amoroso G. and Fassina V., 1983. Stone decay and conservation, Materials science monograph 11, Elsevier, Amsterdam, 453 pp.

Appolonia L., Mariottini M., Lausanne M., 1985. Caractérisation minéralogique et pétrographique des gisants de la cathédrale d' Aoste. In: V Int. cong. on deterioration and conservation of stone 1. (Ed.): G. Félix, Polytechniques Romandes, Lausanne, 23-32.

Arnold D., 1999. Temples of the last pharaohs, Oxford University Press, NY, 373 pp.

Atwood R., 2001. To catch a looter. In: Archaeological survey in Jordan. (Eds.): B. Adams, P. Bienkowski, Sheffield Academic Press, Sheffield, 631-638.

Barakat S., Wilson C., Simčić V., Kojaković M., 2001. Challenges and dilemmas facing the reconstruction of war-damaged cultural heritage: the case study of počitelj, Bosnia-Herzevgovina, Ch. 13. In: Destruction and conservation of cultural property. (Eds.): R. Layton, P. Stone, J. Thomas, Routledge, London, 165-181.

Barroso E., Silva L., Polivanov H., 2006. Weathering and deterioration evaluation of a Brazilian cultural heritage building. In: 10th IAEG International Congress Martin (Eds.): IAEGE, The Geological Society of London, London, No. 290.

Basheer A. and Mosaad S., 2018. Geophysical and hydrogeological evaluation of Pliocene aquifer in East Esna, Egypt. Pure and Applied Geophysics 175, 2251-2267.

Beadnell H., 1905. The relation of the Eocene and Cretaceous system in the Esna-Aswan reach of the Nile Valley. Quart, Journal of Geological Society 61, 607-678.

Benavente D., Garcia del Cura M., Garcia-Guinea J., Sanchez-

Moral S., Ordonez S., 2004. Role of pore structure in salt crystallization in unsaturated porous stone. Journal of Crystal Growth 260, 532-544.

Berry J., 1994. The encapsulation of salt by consolidants used in stone conservation, Journal of Institute of Archaeology 5, 29-37.

Bland W. and Rolls D., 1998. Weathering: An introduction to the basic principles, Hodder Arnold Pub., NY, 275 pp.

Bonazza A., Maxwell I., Drdácký M., Vintzileou E., Hanus C., 2018. Safeguarding cultural heritage from natural and man-made disasters: A comparative analysis of risk management in the EU, Publications Office of the EU, Luxembourg, 207 pp.

Borrelli E., 1999. Porosity, ARC laboratory handbook 2, ICCROM, Rome, 32 pp.

Brikowski T. and Faid A., 2006. Pathline-calibrated groundwater flow models of Nile Valley aquifers, Esna, upper Egypt, Journal of Hydrology 324, 195-209.

Brodie N. and Renfrew C., 2005. Looting and the world's archaeological heritage: The inadequate response. Annual Reviews of Anthropology 34, 343-361.

Brondi M., Fidelibus M., Gragnani R., Tulipano L., 1983. Hydrogeochemical study and distribution of some trace elements in the most important costal springs and groundwater of the Apulian region "Southern Italy". Geologia Applicata e Idrogeologia XVIII (2), 65-80.

Bunson M., 2002. Encyclopedia of ancient Egypt, revised edition, Facts on File Inc., NY, 320 pp.

Campos E., 2009. A groundwater flow model for water related damages on historic monuments - Case study West Luxor, Egypt, VATTEN 65, 247-254.

Camuffo D., 1995. Physical weathering of stones. Science of The Total Environment 167, 1-14.

Canti M. and Linford N., 2000. The effects of fire on archaeological soils and sediments: Temperature and solour relationships. In: Proceedings of the Prehistoric Society, Vol. 66. (Ed.): J. Gardiner, American Political Science Association, USA, 385-395.

Cardella C., Benavente D., Rodríguez-Gordillo J., 2008. Weathering of limestone building material by mixed sulfate solutions: Characterization of stone microstructure, reaction products and decay forms. Materials Characterization 59, 1371-1385.

Chakrabarti B., Yates T., Lewry A., 1996. Effect of fire damage on natural stonework in buildings. Construction and Building Materials 10, 539-544.

Charola E., Pühringer J., Steiger M., 2007. Gypsum: A review of its role in the deterioration of building, materials. Environmental Geology 52, 339-352.

Cohan A., 2004. An examination of archaeological ethics and the repatriation movement respecting cultural property (Part II). Environmental Law & Policy J. 28, 1-116.

Corbeil M., 2004. Applications of X-ray diffraction in conservation science and Archaeometry. Advances in X-ray Analysis 47, 18-29.

Cunliffe E., 2014. Archaeological site damage in the cycle of war and peace: A Syrian case study. J. of Eastern Mediterranean Archaeology & Heritage Studies 2, 229-247.

Daly C., 2011. Climate change and the conservation of archaeological sites: A review of impacts theory. Conservation and Management of Archaeological Sites 13, 293-310.

De Geyter G., 1985. Petrographical characterization of siliceous natural building stones in Northern Belgium. In: V Int. cong. on deterioration and conservation of stone 1. (Ed.): G. Félix, Polytechniques Romandes, Lausanne, 3-11.

Delgado Rodrigues J., 1976. Estimation of the content of clay minerals and its significance in stone decay. In: 2nd International Symposium on deterioration of building stones. (Ed.): Th. Skoulikidis, National Technical University of Athens, Greece, 105-108.

Delgado Rodrigues J., 2001. Swelling behaviour of stones and its interest in conservation. An appraisal. Materiales de Construcción 51 (263-264), 183-195.

El-Bayomi G., 2007. The geomorphological hazards in the archaeological area West of Qena bend. J. of Applied Sciences Research. 3, 175-184.

El-Fakharany Z. and Fekry A., 2014. Assessment of New Esna barrage impacts on groundwater and proposed measures. Water Science 28, 65-73.

El-Gohary M., 1996. A comparative study of deterioration causes and methods of conservation and maintenance of stone monuments in site with application on Ramsis II Temple in Abydos and Nektenebo II temple in Bahbit El-Haggara, Dissertation, Cairo Univ, Egypt. 187 pp.

El-Gohary M., 1999. The geochemistry of ground water in Esna temple area: A technical report, Institute of engineering geology, Rome University, Italy, 32 pp.

El-Gohary M., 2000. Effect of groundwater on sandstone used in some Egyptian temples in upper Egypt with scientific and application methods for its conservation, Dissertation (Joint Programs-Conservation dept., Faculty of Archaeology - Cairo Univ., Egypt & Institute of Geology, Faculty of Engineering - Rome University), Italy, 132 pp.

El-Gohary M., 2007. Degradation of limestone buildings in Jordan: Working effects and conservation problems-Critical study according to international codes of practice. Adumatu 16, 7-24.

El-Gohary M., 2008. Air pollution and aspects of stone degradation "Umayyed Liwān- Amman citadel as a case study". Journal of Applied Sciences Research 4, 669-682.

El-Gohary M., 2010. Investigation on limestone weathering of El-Tuba minaret El Mehalla, Egypt: A case study. MAA 10, 61-79.

El-Gohary M., 2011. Chemical deterioration of Egyptian limestone affected by saline water in. IJCS 2, 17-28.

El-Gohary M., 2012. Behavior of treated and un-treated lime mortar before and after artificial weathering. International Journal of Restoration of Buildings and Monuments 18, 369-380.

El-Gohary M., 2013. Evaluation of treated and un-treated Nubia sandstone using ultrasonic as a non destructive technique. Journal of Archaeological Science 40, 2190-2195.

El-Gohary M. and Al-Shorman A., 2010. The impact of the climatic conditions on the decaying of Jordanian basalt at Umm Qeis: Exfoliation as a major deterioration symptom. MAA 10, 143-158.

Elia R., 1997. Looting, collecting, and the destruction of archaeological resources. Nonrenewable Resources 6, 85-98.

Elizabeth C., 2008. Archaeological site looting: the destruction of cultural heritage in Southern Iraq. In: Catastrophe! The looting and destruction of Iraq's past. (Eds.): G. Emberling and K. Hanson, The Oriental Institute of the University of Chicago, USA, 65-80.

Emara A. and Korany M., 2016. An analytical study of building materials and deterioration factors of Farasan heritage houses, and the recommendations of conservation and rehabilitation (German house case study). Procedia-Social and Behavioral Sciences 216, 561-569.

Feilden B., 2003. Conservation of historic buildings, 3rd ed. Architectural Press, NY, 408 pp.

Fidelibus M., 1993. Evoluzione chimic delle acque sutterranne circolanti nel sistema idrogeologico sell' acquifero carbonatico carsico e costiero della Murgia (Puglia). Geologia Applicata e Idrogeologia XXVIII, 439-447.

Gauri L. and Holdren G., 1981. Preliminary report on the deterioration of stone at the sphinx. Newsletter of American Research Center in Egypt 114, 35-47.

Geweely N. and Afifi H., 2011. Bioremediation of some deterioration products from sandstone of archeological Karnak temple using stimulated irradiated Alkalo-thermophilic purified microbial enzymes. Geomicrobiology 28, 56-67.

Gimez Moral F., 1994. Conservation of the historic center of Quito: La compania de Jesus church as a model project in the restoration of monuments. In: The conservation of monuments in the Mediterranean basin. (Eds.): V. Fassina, H. Ott, F. Zezza, Soprintendenza ai beni artistici e storici di Venezia, Italy, 717-720.

Gomez-Heras M., McCabe S., Smith B.J., Fort R., 2009. Impacts of fire on stone-built heritage an overview. J. of Architectural Conservation 15 (2), 47-58.

Grimmer A., 1984. A glossary of historic masonry deterioration problems and preservation treatments, National Park Service, Preservation Assistance Division, Washington, 67 pp.

Halsey D., Dews S., Mitchell D., Harris F., 1996. Influence of aspects on sandstone weathering: the role of climatic cycles in flaking and scaling. In: 8th International Congress on deterioration and conservation of stone. (Ed.): J. Riederer, Möller Druck und Verlag, Berlin, 849-858.

Hardy R. and Tucker M., 1989. X-Ray power diffractions of sediments. In: Techniques in Sedimentology. (Ed.): M. Tucker, Blackwell Scientific Publications, Oxford, 191-282.

Helmi F., 2000. Geoegyptology of Al-Muzawaka tombs, Dakhla Oases, Egypt. In: 9th International Congress on deterioration and conservation of stone. (Ed.): V. Fassina, Elsevier, Venice, 99-107.

Hernanz A., Bratu I., Marutoiu O., Marutoiu C., Gavira-Vallejo J., Edwards H., 2008. Micro-Raman spectroscopic investigation of external wall paintings from St. Dumitru's Church, Suceava, Romania. Analytical and Bioanalytical Chemistry 392, 263-268.

Hoyos M., Soler V., Cananaveralj C., Sanchez-Moral S., Sanz-Rubio E., 1998. Microclimatic characterization of a karstic cave: Human impact on micro environmental parameters of a prehistoric rock art cave (Candamo cave, northern Spain). Environmental Geology 33, 231-242.

Huges H., 1995. Theft, burglary and vandalism. In: The protection of historic buildings and their artistic contents against crime and wilful damage. (Eds.): CE and DMLMFC, Council of Europe Press, Ministry of the Flemish Community, Netherlands, 119-128.

Hughes M., Cowell M., Craddock P., 1976 Atomic absorption techniques in archaeology. Archaeometry 18, 19-37.

Humble W., 2019. Dictionary of geology and mineralogy, Wentworth Press, NY, 288 pp.

Jakhrani A., Samo S., Sobuz H., Uddin Md., Ahsan M., Hasan N., 2012. Assessment of dissolved salts concentration of seawater in the Vicinity of Karachi. Int. J. of Structural and Civil Engineering 1 (2), 61-69.

James R., 1980. Stone consolidating materials, a status report, National Bureau of Standards, Washington DC, 66 pp.

József Z. and Williams R., 2005. Bentonite, Kaolin and selected clay minerals: Environmental health criteria, 231, WHO, UN Environment Programme, Geneva, 196 pp.

Kassab M., Abu Hashish M., Nabawy B., Elnaggar O., 2017. Effect of kaolinite as a key factor controlling the petrophysical properties of the Nubia sandstone in central Eastern Desert, Egypt. Journal of African Earth Sciences 125, 103-117.

Kersel M. and Chesson M., 2013. Looting matters: Early Bronze age cemeteries of Jordan's southeast Dead Sea plain in the past and present. In: The Oxford Handbook of the Archaeology of Death and Burial. S. Tarlow, L. Stutz. (Eds.): Oxford University Press, Oxford 677-694.

Kidd S., 1995 Heritage under fire: some problems in the protection of historic buildings from fire. In: The protection of historic buildings and their artistic contents against crime and wilful damage. (Eds.): CE and DMLMFC, Council of Europe Press, Ministry of the Flemish Community, Netherlands, 77-94.

Klark I. and Fritz P., 2013. Environmental isotopes in hydrology, CRC Press/Lewis Pub., USA, 342.

Klemm D. and Klemm R., 2001. The building stones of ancient

Egypt - a gift of its geology. African Earth Sciences 33, 631-642.

Kühlenthal M. and Fischer H., 2000. Guidelines and procedures for the restoration of the monuments in Petra. In: Petra. (Eds.): M. Kühlenthal and H. Fischer, Arbeitshefte des bayerischen landesamtes für Denkmalpflege. Byerisches Landesamt für Denkmalpflege, München, 84-86.

Kuzucuoglu A., 2009. Earthquake and vandalism Impact on cultural heritage. In: Int. Symp. on historical earthquakes and conservation of monuments and sites in the Eastern Mediterranean region. (Eds.): Istanbul Technical University, Istanbul, 1-4.

Lahiri N., 2001. Destruction or conservation? Some aspects of monument policy in British India (1899-1905). In: Destruction and conservation of cultural property. (Eds.): R. Layton, P. Stone, J. Thomas, Routledge, London, 264-275.

Laue S., Böhm C., Jeannette D., 1996. Salt weathering and porosity-examples from the crypt of St. Maria im Kapitol, Cologen. In: 8th Int. cong. on deterioration and conservation of stone. (Ed.): J. Riederer, Möller Druck und Verlag, Berlin, 513-522.

Lazzari M., Geraldi E., Lapenna V., Loperte A., 2006. Natural hazards vs human impact: an integrated methodological approach in geomorphological risk assessment on the Tursi historical site, Southern Italy. Landslides 3, 275-287.

Lubelli B., Van Hees R., Groot C., 2006a. Sodium chloride crystallization in a "salt transporting" restoration plaster. Cement and Concrete Research 36, 1467-1474.

Lubelli B., Van Hees R., Huinink H., 2006b. Hygric dilation behavior of NaCl contaminated lime-cement mortar. In: 7th European Conference "SAUVEUR" Safeguarded Cultural Heritage Understanding & Viability for the Enlarged Europe 1. (Eds.): M. Drdácký and M. Chapuis, Academy of Sciences of the Czech Republic, Prague, 141-152.

Marey H., Kantiranis N., Stratis J., 2010. Salt damage on the wall paintings of the festival temple of Thutmosis III, Karnak temples complex, Upper Egypt. A case study. IJCS 1 (3), 133-142.

Meloni P., Carcangiu G., Palomba M., Enzo S., Carboni M., Cocco O., Casti M., Murru A., Farci A., Ruggieri A., 2015. Durability of repair mortars used in restoration of a Sardinian coastal tower: assessment after ten years. In: Defensive Architecture of the Mediterranean. XV to XVIII centuries. (Ed.): P. Rodríguez-Navarro, Editorial Universitat Politècnica de València, Spain, 397-403.

Metz V. and Ganor J., 2001. Stirring effect on Kaolinite dissolution rate. Geochimica et Cosmochimica Acta 65, 3475-3490.

Moncmanová A., 2007. Environmental factors that influence the deterioration of materials. In: Environmental deterioration of materials. (Ed.): A. Moncmanová, WIT Press, USA, 1-25.

Montet P., 1961. Géographie de l'Égypte ancienne, Vol. 2, La Haute Égypte, Impr. Nationale, Paris, 14 pp.

Mora Navarro G., López Doncel R., Espinosa Pesqueira M., Wedekind W., 2016. Weathering and deterioration of building stones in templo Mayor, Mexico City. In: 13th International Congress. on deterioration and conservation of stone II. (Eds.): J. Hughes and T. Howind, University of the West of Scotland, Paisley, 117-124.

Nascimento U., Oliveira R., Graça R., 1968. Rock swelling test. In: International Symposium on determination of the properties of rock masses in foundations and observation of their behavior. (Ed.): ISRM, Editorial Blume, Madrid-Barcelona, 363-365.

Nickens P., Larralde S., Trucker G., 1981. A survey of vandalism to archaeological resources, Cultural Resources Series, No, 11, Bureau of Land Management, Colorado, 169 pp.

Nicu I., 2017. Natural hazards - A threat for immovable cultural heritage. A review 8, 375-388.

Ostrasz A., 1997. The citadel of Amman: The conservation and restoration of the Ayyubid tower. ADAJ 41, 395-402.

Papida S., Murphy W., May E., 2000. Enhancement of physical weathering of building stones by microbial populations. International Biodeterior Biodegrad 46, 305-317.

Perera N., 2017. The destruction of statues in late antique Egypt: A widespread phenomenon or Christian Polemic?, Dissertation., University of Ottawa, 75 pp.

Pettijohn F., 1983. Sedimentary Rocks, 3rd ed., Harper Collins, USA 526 pp.

Pozo-Antonio J., Rivas T., Carrera F., García L., 2018. Deterioration processes affecting prehistoric rock art engravings in granite in NW Spain. Earth Surface Processes and Landforms 43, 2435-2448.

Price W. and Errington J., 1998. Guidelines for metal leaching and acid rock drainage at Minesites in British Columbia, Technical report, British Columbia Ministry of Energy and Mines, London, 86 pp.

Přikryl R., Svobodová J., Žák K., Hradil D., 2004. Anthropogenic origin of salt crusts on sandstone sculptures of Prague's Charles Bridge (Czech Republic): Evidence of mineralogy and stable isotope geochemistry European Journal of Mineralogy 16, 609-618.

Pulido-Bosch A., Rigol-Sanchez J., Vallejos A., Andreu J., Ceron J., Molina-Sanchez L., Sola F., 2018. Impacts of agricultural irrigation on groundwater salinity. Environmental Earth Sciences 77, 197, https://doi.org/10.1007/s12665-018-7386-6.

Queisser A., Platen H., Fuerst M., 1985. Rebound and ultrasonic investigations on freestones of Bamberg area, F. R. Germany. In: V International Congress on deterioration and conservation of stone 1. (Ed.): G. Félix, Polytechniques Romandes, Lausanne, 79-86.

Quinn P., Bates T., Schulz K., Coffman D., Frossard A., Russell L., Keene W., Kieber D., 2014. Contribution of sea surface carbon pool to organic matter enrichment in sea spray aerosol. Nature Geoscience 7, 228-232.

Reedy Ch., 1994. Thin-section petrography in studies of cultural materials. JAIC 33 (2/4), 115-129.

Renfrew C., 2000. Loot, legitimacy and ownership: The ethical crisis in archaeology, Duckworth. London, 160 pp.

Riganti V., Specchiarello M., Rossetti R., Tortelli M., Veniale F., Zezza U., 1993. Air pollution and micro climate influences on stone decay of monuments in urban and extra urban areas (Pavia-Lombardy, Italy). In: Conservation of stone and other materials 1. (Ed.): J. Thiel, RILEM, London, 196-203.

Robertson I. and Eggleton R., 1991. Weathering of granitic muscovite to kaolinite and halloycite and of plagioclase-derived kaolinite and halloycite. Clays and clay minerals 39, 113-126.

Rodríguez-Pascua M., Pérez-López R., Giner-Robles J., Silva P., Garduño-Monroy V., Reicherter K., 2011. A comprehensive classification of Earthquake archaeological effects (EAE) in archaeoseismology: Application to ancient remains of Roman and Mesoamerican cultures. Quaternary International 242, 20-30.

Rollinson H., 1993. Using geochemical data valuation, presentation, interpretation, Longman group, London, 344 pp.

Ruedrich J., Bartelsen T., Dohrmann R., Siegesmund S., 2011. Moisture expansion as a deterioration factor for sandstone used in buildings. Environmental Earth Science 63, 1545-1564.

Said R., 1961. Tectonic framework of Egypt and its influence on distribution of foraminifera. Bulletin of the American Association of Petroleum Geologists 45, 198-2018.

Siedel H. and Klemm W., 2000. Evaluation of the environmental influence on sulphate salt formation at monuments in Dresden (Germany) by sulphur isotope measurements. In "9th International Congress of on Deterioration and Conservation of Stone. (Ed.): V. Fassina, Elsevier, Venice, 401-409.

Silva P., Borja F., Zazo C., Goy J., Bardají T., De Luque L., Lario J., Dabrio C., 2005. Archaeoseismic record at the ancient Roman city of Baelo Claudia (Cádiz, South Spain). Tectonophysics 408 (1-4), 129-146.

Singer A. and Amiel A., 1974. Characteristics of Nubian Sandstone-derived soils. Journal of Soil Science 25, 310-319.

Sivan R., 1997. The presentation of archaeological sites. In: Int. conf. the conservation of archaeological sites in the Mediterranean region. (Ed.): M. De la Torre and Paul Getty, USA, 51-62.

Skoulikidis T. and Beloyannis N., 1984. Investigation of marble sulfation-reconversion of gypsum films into calcite on the surfaces of monuments and statues. Studies in Conservation 29, 197-204.

Sleater G., 1973. A review of natural stone preservation, NBSIR 74-444, National Bureau of Standards, Washington, DC, 35 pp.

Smith B., 1994. Weathering processes and forms. In: Geomorphology of desert environments. (Eds.): A. Abrahams and A. Parsons, Routledge Chapman & Hall, London, 39-63.

Smith B. and McGreevy J., 1988. Contour scaling of sandstone by salt weathering under simulated hot desert conditions. Earth Surface Processes and Landforms 13, 697-705.

Steiger M., 2005. Crystal growth in porous materials-I The crystallization pressure of large crystals. Journal of Crystal Growth 282 (3-4), 455-469.

Stone E., 2008. Patterns of looting in southern Iraq, Antiquity 82, 125-138.

Stovel H., 1998. Risk preparedness: A management manual for world cultural heritage, ICCROM, Rome, 145 pp.

Szemerey-Kiss B. and Torok A., 2017. The effects of the different curing conditions and the role of added aggregate in the strength of repair mortars. Environmental Earth Sciences 76 (284), https://doi.org/10.1007/s12665-017-6597-6.

Teijgeler R., 2006. Preserving cultural heritage in times of conflict, Ch. 9. In: Preservation management for libraries, archives and museums. (Eds.): G. Gorman and J. Sydney, Facet Publishing, London, 133-165.

UWMG., 2002. Damage and misuse, the woodland trust, England. Urban woodland management guide 1, www.woodland-trust.org.uk/policy/publications. htm. Accessed (15 Jan 2018).

Vella C., Bocancea E., Urban T., Knodell A., Tuttle C., Alcock S.E., 2015. Looting and vandalism around a world heritage site: Documenting modern damage to archaeological heritage in Petra's hinterland, Journal of Field Archaeology 40, 221-235.

Vicente M., Inigo A., Garcia-Talegon J., Trujillano R., Sanz L., Cerreta A., Molina E., Rives V., 1994. Conservation studies in weathering of sandstone from the Romanesque façade of the church of San Julian (Salamanco, Spain). In: The conservation of monuments in the Mediterranean basin. (Eds.): V. Fassina, H. Ott, F. Zezza, Soprintendenza ai beni artistici e storici di Venezia, Italy, 693-696.

Webster A. and May E., 2006. Bioremediation of weathered-building stone surfaces. Trends Biotechnol 24, 255-260.

Wilkinson R., 2000. The complete temples of ancient Egypt, Thames & Hudson, USA, 256 pp.

Williams L., 2018. Vandalism to cultural resources of the rocky mountain West, Forgotten Books 198 pp.

Winkler E., 1996. Properties of marble as building veneer. International Journal of Rock Mechanics and Mining Sciences 33, 215-218.

World Heritage Committee., 2009. World heritage 33 COM, World Heritage in Danger, Compendium I, Seville, Spain, 109 pp.

Wüst R. and Schülchter Ch., 2000. The origin of soluble salts in rocks of the Thebes mountains, Egypt: The damage potential to ancient Egyptian wall art. JAS 27, 1161-1172.

Yaldiz E., 2010. Climate effects on monumental buildings. In: BALWOIS (Ed.), Institut Balkanique de l'Eau et de l'Environnement, Ohrid, Republic of Macedonia, 1-10.

Yocom J., 1958. The deterioration of materials in polluted atmospheres. Journal of the Air Pollution Control Association 8, 203-208.

Zimmerman S., De Paoli N., Krim A., Stott P., Bradley J., 1988. Historic & archaeological resources of the Connecticut River valley: A framework for preservation decisions, The Massachusetts Historical Commission, USA, 351 pp.