SCIENTIFIC CULTURE
www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 7, No. 3, (2021), pp. 53-63
Open Access. Online & Print

DOI: 10.5281/zenodo.4916505

THE EFFECT OF WILD PIGEON EXCRETA ON THE WALL PAINTING OF RAMSES III TEMPLE AT MEDINET HABU, LUXOR

Mahgoub A. Ahmed[1*], Mona F. Ali[2], Nabil A. Bader[3], Rafat Khalaphallah[4]

[1]Conservation Department, Faculty of Archaeology, South Valley University, Egypt
[2]Conservation Department, Faculty of Archaeology, Cairo University, Giza, Egypt
[3]Conservation Department, Faculty of Archaeology, Zagazig University, Egypt
[4]Department of Microbiology, Faculty of Agriculture, South Valley University

Received: 27/03/2021
Accepted: 26/06/2021
Corresponding author: Mahgoub A. Ahmed (mahgoub@arch.svu.edu.eg)

ABSTRACT

The archaeological buildings in Upper Egypt are exposed to many deterioration factors. The wild pigeon that lives in Habu Temple (Luxor) is considered one of the most deterioration factors causing damage to the archaeological buildings. Various mechanisms and forms of damage occur by wild pigeon. The current research aims to study the physical and chemical effects of wild pigeon's excrements on sandstone and wall paintings. The analytical study by X-ray fluorescence (XRF) and X-ray diffraction (XRD) of wild pigeon's excrement and paintings was conducted. USB digital microscope was used to examine wild pigeon droppings adhering to the surface of paints. The pH of wild pigeon excrements was measured using a pH meter. Analysis by XRD and XRF revealed a change in the chemical composition of painting components due to the reaction of the acidic excreta with sandstone and various painting components. This reaction led to the formation of sulfate and carbonate salts, which caused the decay of the archaeological paints and stones. Pigment minerals such as hematite (Fe_2O_3) for the red color and malachite ($Cu_2CO_3(OH)_2$) for the green color were identified. The examination showed that the excrements were strongly adhered on the paint surface and penetrated into the inner painting surface. Excrements led to the detachment of pigment materials from paint surface and granular disintegration of sandstone. The pH of the excreta is changed over time. This study provides a greater understanding of the effects of wild pigeon excreta on the archeological stone and paintings.

KEYWORDS: Habu temple, Ramses III, wild pigeon, excrements, biodeterioration, wall painting

1. INTRODUCTION

Pigeons living in ancient Egyptian temples and in mountainous areas adjacent to the urban settlements are a type of pigeon of the Eurasian Species (Stringham *et al.*, 2012) (Amirkhani *et al.*, 2009). They are a hybrid of European and Asian origin. Although this type of pigeon lives essentially in areas of rocky slopes, it adapted gradually with urban settlements taking them as a suitable environment for its habitation (Hetmański *et al.*, 2011). Recently, wild pigeons are considered a threat to the communities in which they settle (Gavris, 2011). Pigeon excrement poses a major problem for property owners and the historical and archaeological buildings in different countries of the (Razani *et al.*, 2018). The World Health Organization (WHO) considers wild pigeons to be a problem of public health. Pigeons transmit dangerous viruses, bacteria, fungi, and parasites that can cause health problems in both humans and animals. Several works of literature have studied the role of birds in the transport of different microbial species (Sachse *et al.*, 2012).

The temple of King Ramses III is located in the west bank of Luxor about 600 km south of Cairo (Wilfong, 2013) and it is known as the Temple of Medinet Habu. This temple is the only surviving temple in the west bank (Hölscher, 1941). The temple suffers from many deterioration factors especially biodeterioration by wild pigeon which is considered more harmful than others. Wild pigeons in Habu Temple belong to Columba livia (Giunchi, 2012). This species prefers nesting on the architectural elements of these buildings and is the main cause of damage among the different species of birds to the archaeological buildings. Wild pigeons are spread throughout the temple: above the columns capitals and cornices as shown in Figure1, between building blocks, and inside engraved places as shown in Fig. 2. The environmental conditions of temples are suitable for the wild pigeons due to their similarity with the basic infrastructure of the wild pigeon, where the edges and holes of buildings and bridges are similar to those found in the wildlife (Przybylska *et al.*, 2012), in addition to the availability of the required materials for building their nests. The current urban structure has become a source of nutrients that are one of the important things for pigeons to be found. Perhaps the ability of wild pigeons to use the protein found in human food remains is also important in its spread in the urban structures among human populations. Wild pigeon continues to reproduce over the year and lay two eggs at a time that hatch after 18 days. Pigeon chicks need to feed for 28-32 days to reach the age of flying.

Wild pigeon excrements cause chemical damage of archaeological stones (Heddema *et al.*, 2006), since excrements contain some chemical acids such as phosphoric, nitric, and uric acid in addition to some salts. These acids and salts react with the various components of stone and paints, dissolving their mineral components (Doehne & Price, 2010; Sachse *et al.*, 2012; Spennemann & Watson, 2017) indicated the role of the wild pigeon excrements in causing significant damage to the stones especially sandstone by uric acid.

Both sandstone and limestone contain calcium carbonate as a highly mineral component and it varies from stone to stone depending on the type. Calcium carbonate is affected by acids resulting from acid rains and air pollution. Deposits from bird excrements (either directly or indirectly) cause chemical damage to stone surfaces just as acid rain does. Wild pigeons' droplets cause several deterioration forms on archaeological buildings such as surface staining of stone surfaces (Spennemann *et al.*, 2018) Birds' excrements contain plant seeds which grow on a stone surface under the appropriate conditions, causing microbial deterioration of stones. Wild pigeon excrements also contain other ingredients that are brown and green, which are closer organic materials with a thin layer of urea and mucus (Kear, 1963; Halsema *et al.*, 1988). These ingredients are dissolved by rain and create varied coloured patches on stone and paint surfaces as shown in Fig. 3 (Spannemann & Watson, 2018). Pigeon excreta are an appropriate environment for growing some *Cryptococcus* microbes. The growth of these microbes is attributed to the high acidity of bird excreta because they cannot survive in alkaline conditions (Abegg *et al.*, 2006). Also, excreta components provide nutrients to other microorganisms such as algae and fungi on which they grow and cause further microbial damage to stones (Helmi *et al.*, 2011; Spannemann & Watson, 2018; Moussa, Badawy & Saber, 2021).

After eating, wild pigeons need about one hour to excrete, depending on the type and quantity of food (Laurila *et al.*, 2003). Wild pigeons consume about 11-26 g /24 hours (Hatt, 2002). A dove can excrete approximately 4-12 kg/year, depending on the amount of food. Also, temperature and dietary timing play a very important role in the quality and quantity of waste from wild pigeons. Several studies of the chemical composition of pigeon excrement showed that pigeon excrements contain 2.0:12.6 mg/d uric acid. These studies did not take into consideration the quality and quantity of food. Also, these studies showed that pigeonholes had high water content, ammonia, carbonate, calcium sulphate, phosphoric acid, potassium, and calcium dioxide (Spennemann & Watson, 2017). Further studies reported that the high percentage of ammonia attributed to the presence of oxidizing bacteria that produce nitrate and uric acid (Wei *et al.*, 2013). The current study relied on collecting the excrement of wild pigeons that live in the temple unlike other research that dealt with this topic through the role of the type of feeding on wild pigeon droppings.

Through observation and examination of the deteriorated archaeological paintings and stones, wild pigeon excrements have been observed to play a main role in deterioration. Wild pigeon droppings cause detachment and discoloration of the pigment materials and granular disintegration, in addition to the aesthetic disfiguration of the archaeological surface. This study aims to diagnose the current state of the damage, studying the chemical and mineralogical composition of wild pigeon excrements, paintings, and archaeological stones to understand their deterioration mechanisms. The approach adopted was to initially examine the influence of the wild pigeon excrements on the archaeological paintings and sandstone of Habu Temple. This was done in terms of wild pigeon excrement composition analysis by XRF, microscopic examination of deteriorated samples, mineralogical analysis of the deteriorated pigment materials, and pH measurements.

Figure 1. Wild pigeon on the archaeological walls of Medinet Habu Temple

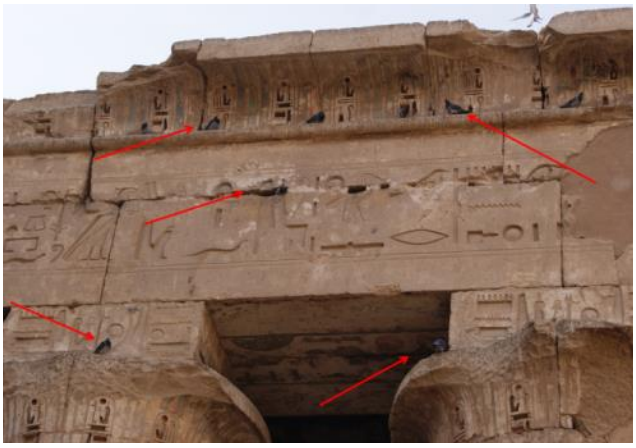

Figure 2. Wild pigeon above the columns, cornices and between building blocks.

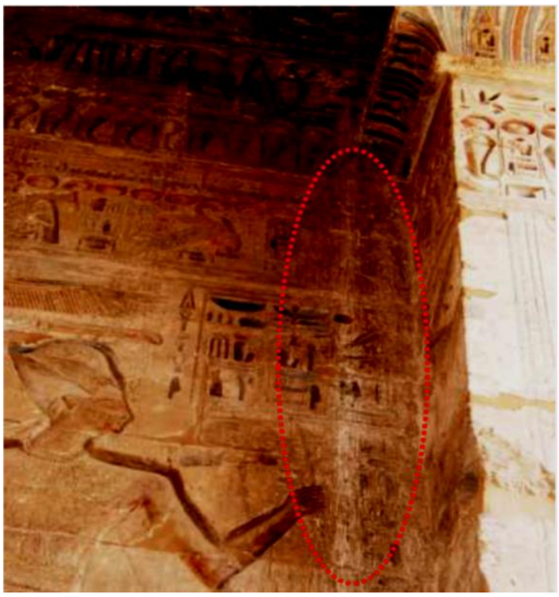

Figure 3 . The effect of wild pigeon excrements on the archaeological paintings at Medinet Habu Temple.

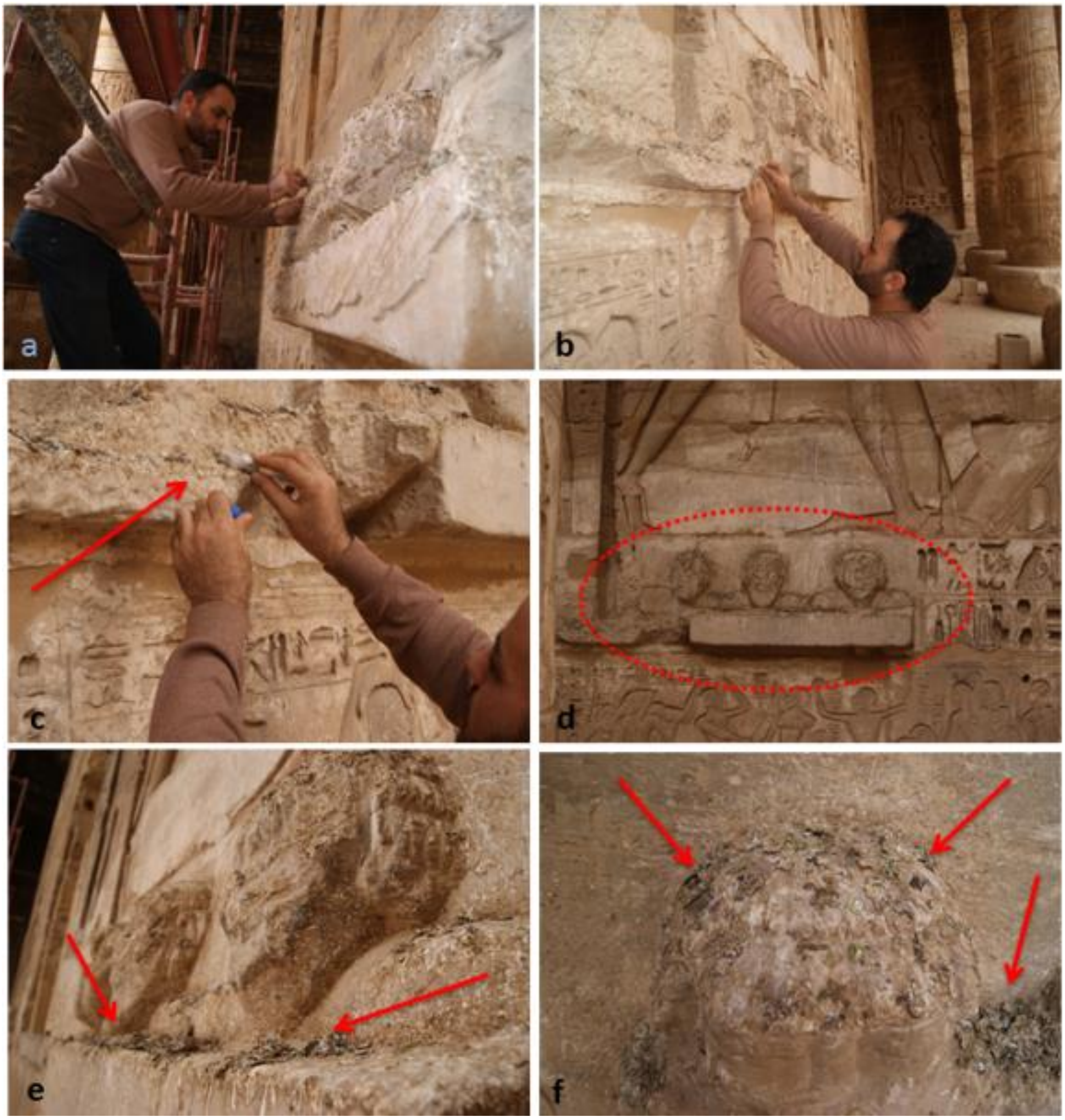

Figure 4. Collecting wild pigeon excrement samples.

2. MATERIAL AND METHODS

2.1. SAMPLING

500 g of wild pigeon droppings was collected from below the temple's stone walls and columns. Then it was kept in the freezer until the laboratory study as shown in Fig. 4. For the mineral and elemental analysis of the bird excrements, the excrement was dried and powdered then 1 g of each sample was analysed. To identify the mineral composition of the pigments, two Samples were collected from deteriorated paintings then powdered in ceramic mortar. 1g of each sample was used for the XRD analysis.

2.2. ANALYTICAL TECHNIQUES

2.2.1. *USB digital microscope*

Portable USB digital microscope was used to examine wild pigeon droppings adherent on archaeological stones surfaces. USB digital microscope (model PZ01 with image sensor 0.3 Mega pixels, its variable magnification ranging from 20 to 500X, photo capture resolution 640x480,320x240 and LED illumination light resource adjustable by the control wheel.

2.2.2. *X-ray fluorescence analysis*

X-ray fluorescence analyser (energy dispersive X-ray fluorescence system (ED-XRF) (JEOL JSX 3222 –

model)) was used. X-ray generator is 5 KV and tube current is from 0.01 to 1.0 mA. X-ray tube is end window type and Be 127 µm thick window. EDS detector is 149 eV energy resolution and from Na to U detectable elements. XRF was used to study the chemical composition of the wild pigeon excrements collected from Habu Temple as shown in Table 1.

2.2.3. *X-ray diffraction analysis*

Mineralogical characterization of the collected excrement and pigment samples was conducted at Central Metallurgical Research and Development Institute (CMRDI) by an X-ray diffractometer, Bruker D8 advance, using CuKα radiation, calibrated against a quartz standard and wavelength of 1.789. Mineralogical interpretations were accessed by PANalytical X'Pert High Score 2.2 software.

2.2.4. *Ph measurement of wild pigeon excrement samples*

This study was conducted to measure the acidity of the wild pigeon excrement (D.H. Spennemann, Pike & Watson, 2017) as follows:

500 g of fresh excrement was collected before being dried. Pigeon excrement was mixed with 200 ml of filtered water. The mixture was mixed well until completely homogeneous. 5 ml of the excrement was taken and placed in a sterilized tube with 16 samples (three replicates for each sample) for a total of 48 samples. These tubes were sealed and placed in the freezer to be standard reference samples. 48 other samples were prepared and then put into tubes with 5 ml of excrement per tube and left open in the laboratory atmosphere. Measured samples were discarded immediately after the measurement was completed by three samples from both standard samples and samples left in the laboratory atmosphere and the process lasted for ten consecutive days. The pH average was recorded in each of the previous measurements, at the end of the first ten days of the measurement, and then the pH was measured every two days, up to the twenty-second day as shown in Table 2. 10 ml of filtered water was added to the sample, to blend it in so as to ease the measurement by using the JenwayModel3540 pH/conductivity meter as shown in Fig. 7.

Figure 5. The wild pigeon excrement sample stored at laboratory atmosphere

Figure 6. The wild pigeon excrement frozen sample (experimental control)

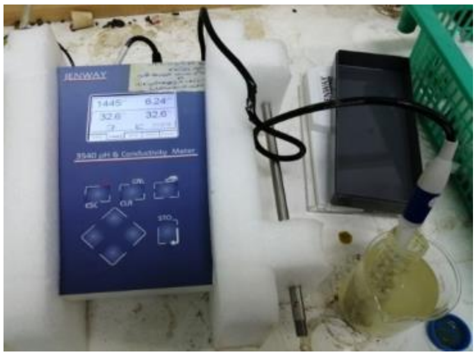

Figure 7. Measuring the PH Value by using Jenway Model 3540 pH/conductivity meter.

3. RESULT AND DISCUSSION

3.1. *USB digital microscope examination.*

The examination by USB digital microscope shows that the pigeon excrement adhered to the surface of the blue, black, and green pigment materials of wall painting as shown in Fig. 8 (a-b-e-f). Also, pigeon excrement penetrated the granules of the archaeological sandstone and caused deterioration and granular disintegration of both stone and pigment materials as shown in Fig. 8 (c). In addition, excrements of wild pigeon caused physical, chemical, and microbial deterioration. The acids and fats of excrement (Kear, 1963) reacted with the chemical composition of both stone and pigment material causing a change in their chemical composition. The excrements of wild pigeon caused microbial deterioration as shown in Fig. 8 (d) which illustrates the presence of fungal hyphae on the surface of the paints.

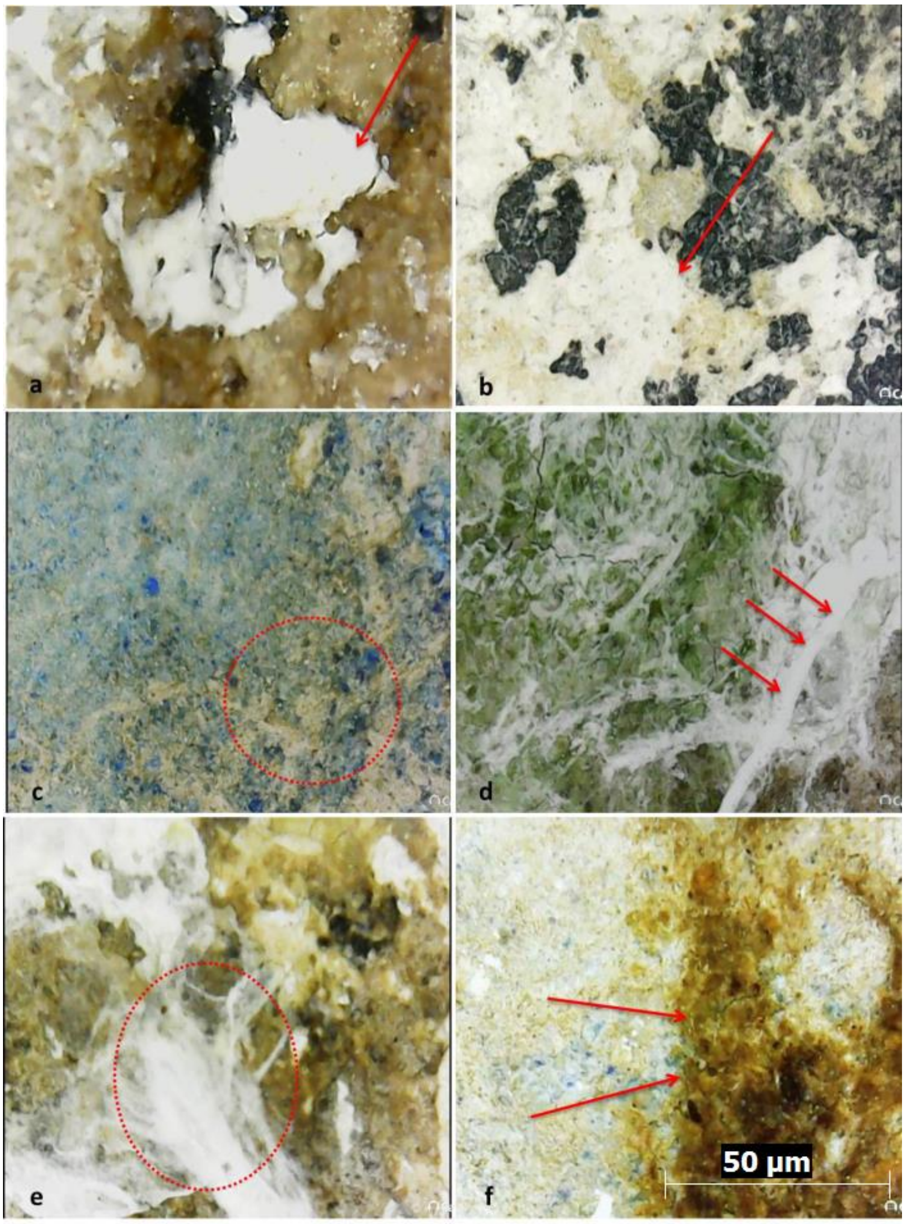

Figure 8 . USB digital microscope examination of the wild pigeon excrement adhered to the archaeological paint surface at Habu Temple.(a) The excrement penetrated the stone grains; (b) the excrement obscured black pigments; (c) discoloration and disintegration of blue pigment; (d) fungal hyphae growth on the paint surface; (e and f) The dry pigeon excrement obscured the paint layer at Habu Temple.

3.2. X-ray fluorescence analysis.

The analysis of the pigeon excrement sample taken from Medinet Habu Temple shows that the sample contained the following elements: silicon (Si), aluminium (Al), manganese (Mn), calcium (Ca), and potassium (K), as shown in Fig. 9 and Table 1. These elements attributed to calcium carbonate ($CaCO_3$), quartz (SiO_2), and gypsum ($CaSO_4 \cdot 2H_2O$). These results are consistent with the results listed by Balogh *et al.* (2019) and Spennemann & Watson, (2017).

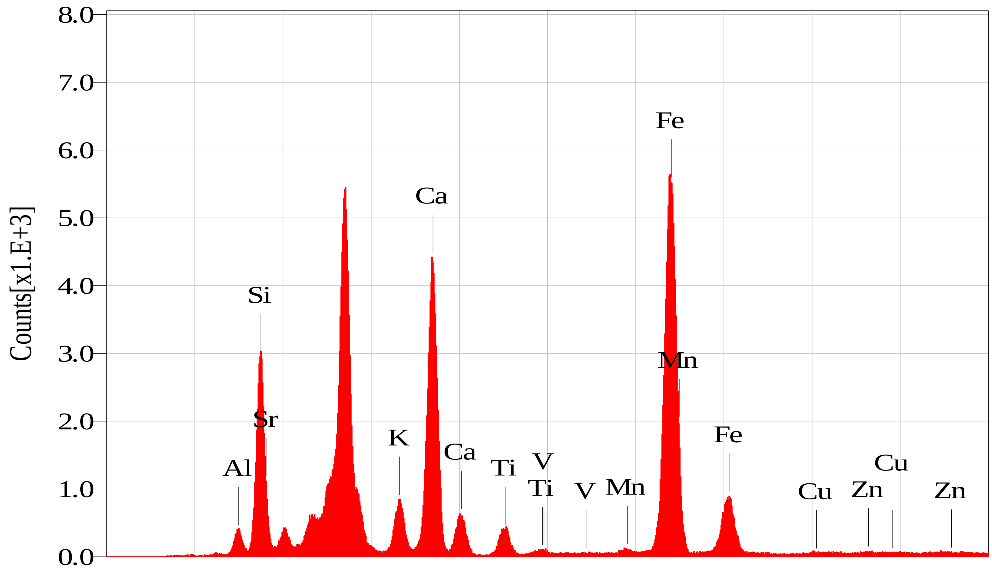

Figure 9. X-ray fluorescence analysis pattern of Pigeon excreta.

Table 1. The elemental composition of wild pigeon excrements at Habu Temple

Element	ms%	mol%	Sigma
Al	6.0168	8.5668	1.1898
Si	24.0539	32.9023	1.2108
K	5.8847	5.7817	0.8268
Ca	31.2630	29.9663	0.7250
Ti	3.2397	2.5983	0.5654
V	0.0564	0.0425	0.4806
Mn	0.5539	0.3873	0.3969
Fe	28.2793	19.4536	0.3782
Cu	0.0860	0.0520	0.4529
Zn	0.1204	0.0708	0.4367
Sr	0.1510	0.0662	0.5199
Ru	0.2951	0.1122	2.2413

3.3. *X-ray diffraction analysis*

The mineralogical analysis using X-ray diffraction method for the pigment materials helps in determining the deterioration mechanisms. Calcite ($CaCO_3$), Dolomite (Ca Mg $(CO_3)_2$), and quartz (SiO_2) were identified in wild pigeon excrements analysis result as shown in Fig. 10. XRD pattern of the red pigment sample showed presence calcium carbonate ($CaCO_3$) and quartz (SiO_2) in the sample of the red pigment which is attributed to accumulation of pigeon excrement at the paint surfaces as shown in Fig. 11. The mineralogical analysis, by XRD, showed the existence of hematite (Fe_2O_3) as a pigment material in the sample, and X-ray diffraction analysis showed the presence of calcium carbonate, calcium sulphate, anhydrite, and quartz in the green pigment sample. The presence of calcium sulphate and calcium carbonate is due to their excretion by wild pigeon excrement and its accumulation on the archaeological surface as shown in Fig. 12. The mineralogical analysis by XRD proved the presence of malachite ($Cu_2CO_3(OH)_2$) mineral as a source of green pigment in the sample.

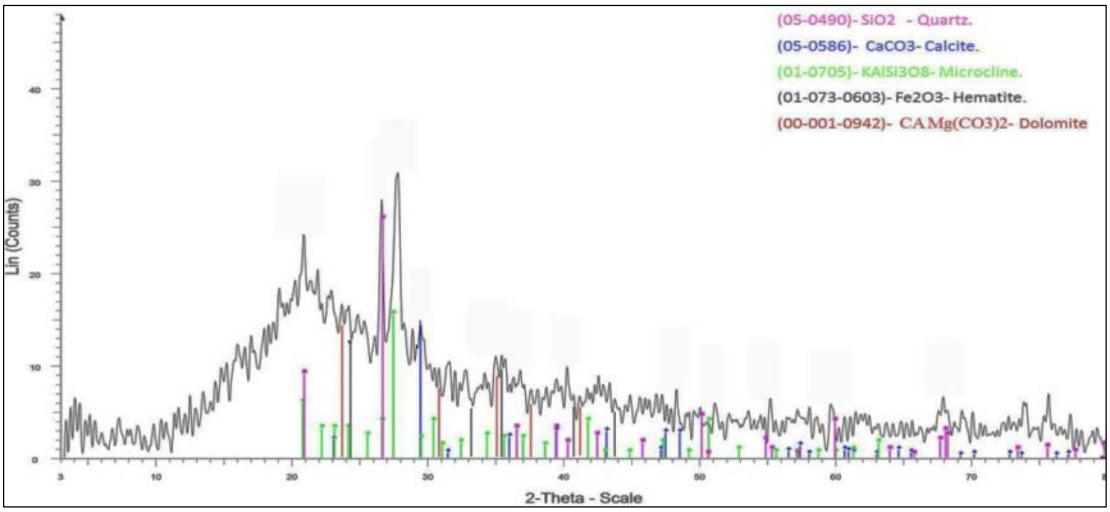

Figure 10. XRD diffractogram of wild pigeon excrement sample.

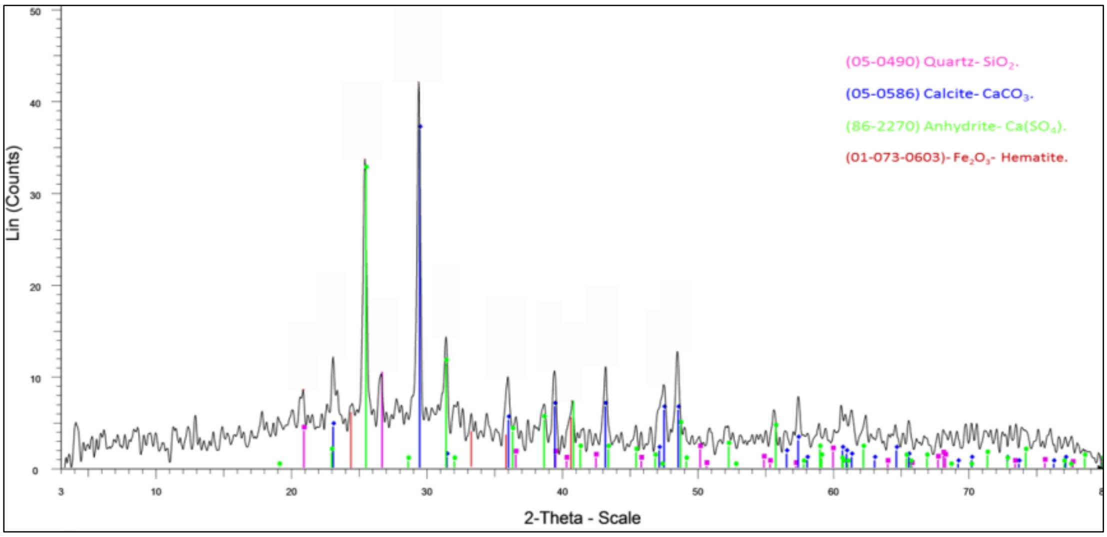

Figure 11. XRD diffractogram of deteriorated red pigment sample.

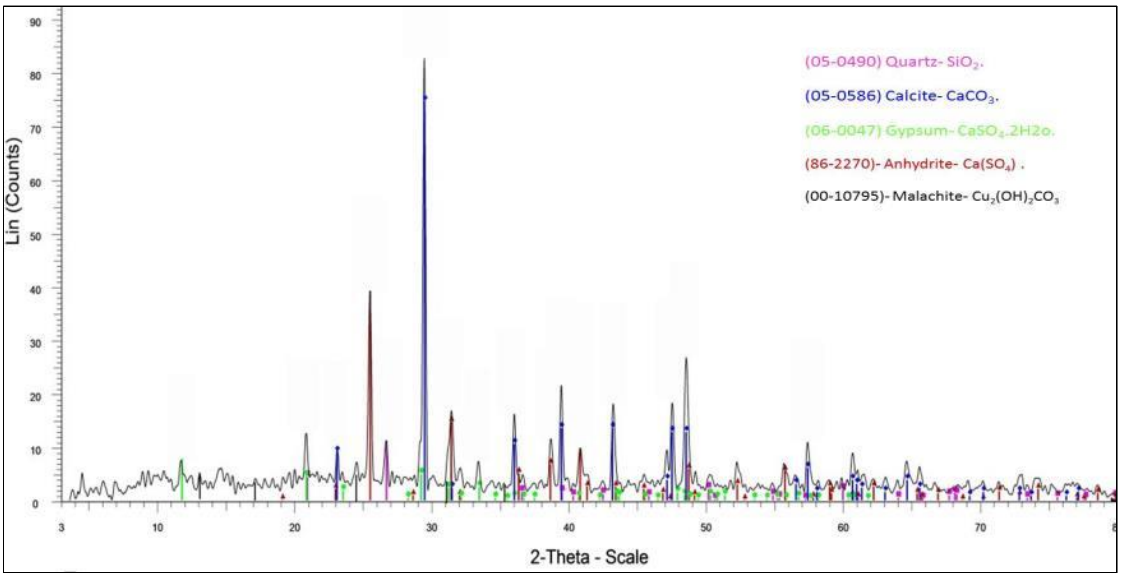

Figure 12. XRD diffractogram of deteriorated green pigment sample.

3.4. *Measuring the ph value.*

The pH of the wild pigeon droppings of the control sample, kept frozen, showed slight change ranging from pH 0.6 to 0.4 as shown in Table 2 and Fig.13. For laboratory samples, pH 5.95 was recorded on the first day because it was still fresh while the samples from the second day to day five showed pH value increase from 8.58 to 8.76, and this value is very high. Beginning from the sixth day, the pH value of the samples in the laboratory atmosphere decreased to record pH = 8.23, the seventh day pH = 7.5, and the eighth day pH = 7. A slight increase in the pH value began to be recorded on the twelfth day pH = 7.11, leading to the 22nd day, in which the pigeon excrement recorded a pH = 7.66.

The pH of bird excrement explains their behaviour on the archaeological stone buildings. It is known that sand limestone is affected by acids (Goldstein & Skadhauge, 1998), dissolving calcium carbonate from limestone and, if present, as a sandstone. As previously reported, bird excrements contain many acids, especially nitric, uric, and phosphoric acid, as well as other organic acids which can cause damage to the various archaeological materials represented in this study.

Table 2.pH of bird excrements in laboratory atmosphere to the pH of bird excrement in the freezer.

day	Laboratory atmosphere sample (PH)	Control sample (PH)
1	5.95	6.24
2	8.76	6.43
3	8.92	6.47
4	8.78	6.48
5	8.58	6.58
6	8.23	6.56
7	7.5	6.8
8	7	6.7
9	7.01	6.67
10	7.37	6.66
12	7.11	7.7
14	6.97	6.68
16	6.91	6.85
18	6.82	6.83
20	7.19	6.94
22	7.66	6.86

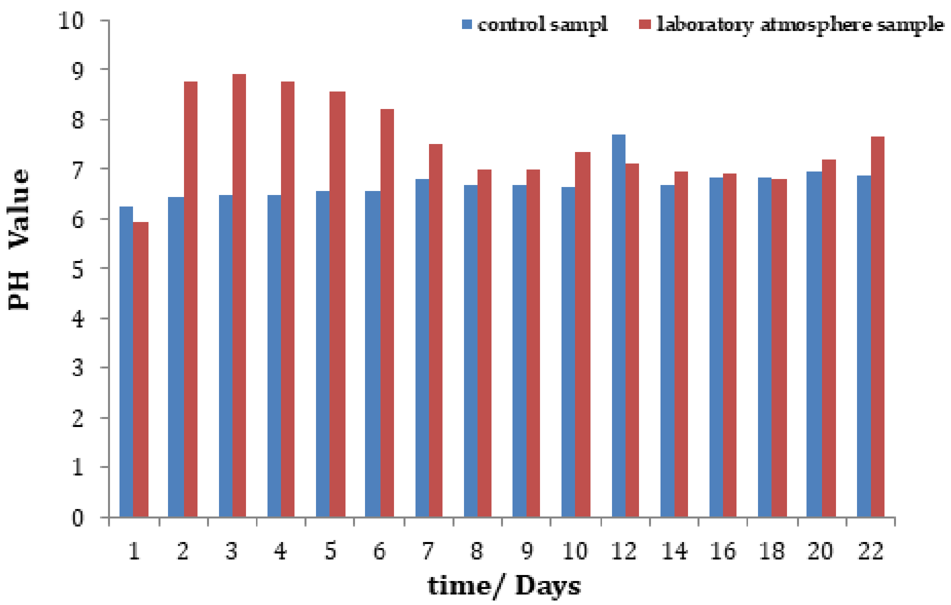

Figure 13. Wild pigeon excrement pH value

4. CONCLUSION

Through observation and examination of the deteriorated wall paintings and stones in Habu Temple, it was found that the Wild pigeons play the main role in deterioration. Its occur detachment and discoloration of the painting materials and cause granular disintegration, aesthetic disfiguration of the archaeological surface. USB digital microscopy analyses detect sticking pigeon excrements to the surface of the paintings. Pigeon excrements attribute to granular disintegration and detachment of the sandstone and pigment materials in addition to obscuring and fading the paintings. The accumulation of pigeon excrements on the surface of the stones and archaeological paintings lead to the growth of different microbial species This was evident from the presence of fungal hyphae growing on pigeon droppings. The XRF analyses show that the chemical constituents of excrement were silicon (Si), aluminum (Al), manganese (Mn), calcium (Ca), potassium (K). The analyses show an enrichment of calcium and potassium associated with the higher abundance of calcium and potassium carbonate. Accordingly, the data from XRF analyses are consistent with the observations under the USB digital microscope. The pH levels varied between the samples kept in the freezer and those in the laboratory atmosphere. This proves that the pH of wild pigeon droppings changed during their presence on the surface of stones and paintings. Leading to the destruction of the archaeological surface.

Wild pigeon excrements were shown to degrade sandstone and paint components through an acid decomposition process, which leads increases the rate of dissolution of stone and painting elements.

Their droppings caused damage to archaeological pigments through the formation of salts of carbonate and calcium sulfate on the surface.

ACKNOWLEDGEMENTS

The authors are grateful to Dr. Yusry Salem, department of Conservation, Faculty of Archaeology, South Valley University, Egypt and Dr. Mahmoud Sabry, department of Geology, Faculty of Science, South Valley university, Egypt for providing facilities to carry out the work.

REFERENCES

Abegg, M. A., Cella, F. L., Faganello, J., Valente, P., Schrank, A., & Vainstein, M. H. (2006). Cryptococcus neoformans and Cryptococcus gattii isolated from the excreta of psittaciformes in a southern Brazilian zoological garden. Mycopathologia, Vol. 161, Issue 2, pp.83-91.

Amirkhani, A., Baghaie, P., Taghvaee, A. A., Pourjafar, M. R., & Ansari, M. (2009). isfahan's dovecotes: remarkable edifices of iranian vernacular architecture. metu Journal of the Faculty of Architecture, Vol. 26(1), pp.177-186.

Balogh, K., Slížková, Z., & Kreislová, K. (2019). The effects of bird excrements on copper and bronze. In *Structural Analysis of Historical Constructions* (pp. 1940-1948). Springer, Cham.

Gavris, G. (2011). Current situation and problems of management of pest birds in the cities of Ukraine. *Julius-Kühn-Archiv*, *432*, 128.

Giunchi, D., Albores-Barajas, Y. V., Baldaccini, N. E., Vanni, L., & Soldatini, C. (2012). Feral pigeons: problems, dynamics and control methods. *Integrated pest management and pest control. Current and future tactics, London, InTechOpen*, pp.215-240.

Goldstein, D.L., & Skadhauge, E. (2000). Renal and extrarenal regulation of body fluid composition. In *Sturkie's avian physiology* (pp. 265-297). Academic Press.

Halsema, W. B., Alberts, H., De Bruijne, J. J., & Lumeij, J. T. (1988). Collection and analysis of urine from racing pigeons (columba livia domestica). *Avian Pathology*, Vol. *17*, Issue 1, pp. 221-225.

Hatt, J. M. (2002, August). Digesta kinetics in feral pigeons (Columha livia). In *Proc Joint Nutrition Symp, Antwerp, Belgium* (pp. 21-25).

Heddema, E. R., Ter Sluis, S., Buys, J. A., Vandenbroucke-Grauls, C. M., van Wijnen, J. H., & Visser, C. E. (2006). Prevalence of Chlamydophila psittaci in fecal droppings from feral pigeons in Amsterdam, The Netherlands. *Applied and Environmental Microbiology*, Vol.72, Issue 6, pp. 4423-4425.

Hetmański, T., Bocheński, M., Tryjanowski, P., & Skórka, P. (2011). The effect of habitat and number of inhabitants on the population sizes of feral pigeons around towns in northern Poland. *European Journal of Wildlife Research*, Vol. *57*, Issue 3, pp.421-428.

Helmi, F. M., Elmitwalli, H. R., Rizk, M. A., & Hagrassy, A. F. (2011). Antibiotic extraction as a recent biocontrol method for Aspergillus niger and Aspergillus flavus fungi in ancient Egyptian mural paintings. *Mediterranean Archaeology and Archaeometry*, 11(2), 1-7.

Hölscher, U., (1941) The Mortuary Temple of Ramses III, Part I. The Excavation of Medinet Habu, Volume 3. Chicago (IL): Oriental Institute.

Kear, J. (1963). The agricultural importance of wild goose droppings. *Wildfowl*, Vol. *14*, Issue14, pp 6.

Laurila, M., Hohtola, E., Saarela, S., & Rashotte, M. E. (2003). Adaptive timing of digestion and digestion-related thermogenesis in the pigeon. *Physiology & behavior*,Vol. *78*, Issue 3,pp. 441-448.

Moussa, A., Badawy, M., & Saber, N. (2021). Chromatic alteration of Egyptian blue and Egyptian green pigments in Pharaonic late period tempera murals. *Scientific Culture*, 7(2), 1-16.

Price, C. A., & Doehne, E. (eds) (2011). Stone conservation: an overview of current research. The Getty Conservation Institute, Los Angeles.

Przybylska, K., Haidt, A., Myczko, Ł., Ekner-Grzyb, A., Rosin, Z. M., Kwieciński, Z., ... & Skórka, P. (2012). Local and landscape-level factors affecting the density and distribution of the Feral Pigeon Columba livia var. domestica in an urban environment. *Acta Ornithologica*, Vol.*47*, Issue 1, pp. 37-45.

Sachse, K., Kuehlewind, S., Ruettger, A., Schubert, E., & Rohde, G. (2012). More than classical Chlamydia psittaci in urban pigeons. *Veterinary microbiology*,Vol. *157*, issue 3-4, pp. 476-480.

Salama, K. K., Ali, M. F., & Moussa, A. M. (2016). Deterioration factors facing mural paintings in el Sakakeny Palace (problems and solutions). *Scientific Culture*, 2, 5-9.

Spennemann, D. H., & Watson, M. J. (2017). Dietary habits of urban pigeons (Columba livia) and implications of excreta pH–a review. *European Journal of Ecology*, Vol. *3,* Issue 1, pp. 27-41.

Spennemann, D. H., & Watson, M. J. (2018). Experimental studies on the impact of bird excreta on architectural metals. *APT Bulletin: The Journal of Preservation Technology*, Vol. *49,* Issue 1, pp. 19-28.

Spennemann, D. H., Pike, M., & Watson, M. J. (2017). Effects of acid pigeon excreta on building conservation. *International Journal of Building Pathology and Adaptation*, 35(1), pp.2-15. https://doi.org/10.1108/IJBPA-09-2016-0023.

Spennemann, D., Pike, M., & Watson, M. J. (2018). Behaviour of pigeon excreta on masonry surfaces. *Restoration of Buildings and Monuments*, 23(1), 15-28.

Wei, S., Jiang, Z., Liu, H., Zhou, D., & Sanchez-Silva, M. (2013). Microbiologically induced deterioration of concrete: a review. *Brazilian Journal of Microbiology*,Vol. *44*,Issue 4, pp. 1001-1007.

Wilfong, T. G. (2013). Medinet Habu (Djeme). *The Encyclopedia of Ancient History*.

Razani, M., & Ahmad Khan Beigi, S. (2018). Preventive Conservation on Control of Destructive Role of Bird's Droppings on stone architecture. *Athar Journal*, 39(83), 29-41.