Identification of Groundwater's Type in Sarabium Archaeological Site – Atfiyah – Egypt and Its Microbiological Effect

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Abstract: Sarabium archaeological site locates in Atfiyah center – Egypt, it belonged to 26th dynasty, the site suffers from the groundwater which affects badly on the deterioration of the building materials there, many microorganisms grow on lime stone carved coffins and ruins, they produce organic compounds which react with lime stone and turn to soluble salts, this is called biological weathering of the lime stone. This research will include the identification of the ground water's type and the microorganisms grown, their visible effect.

Keywords: Sarabium Archaeological Site, Ground Water, Microorganisms, Limestone

1. Introduction

Sarabium archaeological site locates in Atfiyah center – Giza governorate, Apis bull buried in many tombs which Called "Sarabium "like Saqqara Sarabium site but Atfiyah's Sarabium is for the burial of Hathur cow which was the main goddess of Atfiyah's center in this time, the site contains of many tombs for Hathur cow from the 26th dynasty [1]. The site suffers from the existence of groundwater in the carved limestone' coffins because of the short distance between the site and the fields around it (100 meter approx.), the site is lower than the surrounded area and the groundwater aggregates inside the coffins. The groundwater includes some salts which arise in the building materials with capillary system and destroy them by growing inside and make stresses, also the groundwater contains microorganisms which produce organic compounds, these compounds react with building materials and turn them into soluble materials. The result is the loss of the building materials in the end.

2. Materials and Methods

2.1. The Ground Water's Analysis

We took water's sample from one of the limestone's coffins to identify it, the sample analyzed in Water testing central laboratories – Drinking Water and Sanitation Company in Fayoum governorate – Ministry of Housing and Utility - Egypt. Figure (1-3).

2.2. The Analysis of Limestone Ruins

A sample of limestone was analyzed by X - Ray Diffraction (XRD) to identify its components and examined by Scanning Electron Microscope (SEM) to study the surface; also the sample was analyzed by EDAX (Energy dispersive x-ray spectroscopy) to know its mineral elements. Figure (4-6).

2.3. Identification of the Limestone's Ruins Mortar

A sample of mortar was analyzed by X- Ray Diffraction (XRD) to identify its components, examined by Scanning Electron Microscope (SEM) to study the surface, and
examined by Polarizing microscope to identify its components. Figure (7-9).

2.4. The Analysis of Mud Bricks Ruins

A sample of mud bricks was analyzed by X-Ray Diffraction (XRD) to know its components, also examined by Scanning Electron Microscope (SEM) to study the entire texture of the surface with different magnification power, and the Elemental analysis of the sample with EDAX. Figure (10-12).

2.5. Identification of Salts in the Building Materials

A sample of salts' flakes from the limestone ruins was taken and analyzed by X-Ray Diffraction (XRD), examined by Scanning Electron Microscope (SEM) and analyzed by EDAX. Figure (13-15).

2.6. Identification of the Grown Weeds in the Site

A sample of dominant plants or weeds which grew intensively in the site was taken and identified with the plants laboratory in the Agricultural and Biological Research Division – National Research Center – Egypt. Figure (16-18).

2.7. Identification of the Microbiological Effect of the Groundwater

From the water's analysis, we identify the microbiological effect of groundwater on the limestone' Coffins and ruins. Figure (19).

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**Table 1.** Shows the inorganic parameter of the ground water sample.

| No. | Inorganic Parameter       | Unit(s) | Criteria for treated water | Criteria for raw water | % | Uncertainty | LOQ | LOD | Groundwater sample |
|-----|--------------------------|---------|-----------------------------|------------------------|---|-------------|-----|-----|-------------------|
| 1   | Temperature              | °C      | > 5                         |                        |   |             |     |     | NA                |
| 2   | Res. Chlorine            | ppm     | 5                           | 6.6 - 8.5              | 8.4 | 0.108 | 0.032 | 7.89 | 16.28            |
| 3   | pH                       | ppm     | 7.5                         | 7.4 - 8.5              | 8.4 | 0.108 | 0.032 | 7.89 | 16.28            |
| 4   | Total dissolved solids   | ppm     | 1000                        | 8.5                    | 4.4 | 0.126 | 0.011 | 98.2 | 802.4            |
| 5   | Nitrate (NO₃)            | ppm     | 45                          | 20 - 150               | 18 | 7.338 | 4.427 | 98.2 | 802.4            |
| 6   | Total hardness           | ppm     | 10000                       | 500                    | 3.24 | 3.706 | 1.115 | 98.2 | 802.4            |
| 7   | Total hardness           | ppm     | 10000                       | 500                    | 3.24 | 3.706 | 1.115 | 98.2 | 802.4            |
| 8   | Permanent hardness      | ppm     | 150                         | 100                    | 4.1 | 0.486 | 0.106 | 142.19 | 1.117          |
| 9   | Calcium hardness         | ppm     | 150                         | 100                    | 4.1 | 0.486 | 0.106 | 142.19 | 1.117          |
| 10  | Magnesium hydroxide      | ppm     | 250                         | 20 - 1200              | 12.9 | 0.919 | 0.031 | 1002.09 | 1.117          |
| 11  | Chlorides                | ppm     | 150                         | 100                    | 4.1 | 0.486 | 0.106 | 142.19 | 1.117          |
| 12  | Fluoride                 | ppm     | 10000                       | 500                    | 3.24 | 3.706 | 1.115 | 98.2 | 802.4            |
| 13  | Sulfate                  | ppm     | 25                          | 18 - 150               | 16.5 | 0.919 | 0.031 | 1002.09 | 1.117          |
| 14  | HCO₃                     | ppm     | 100                         | 500                    | 3.24 | 3.706 | 1.115 | 98.2 | 802.4            |
| 15  | PO₄                      | ppm     | 5                           | 0.5                    | > 0.5 | 0.036 | 0.011 | 16.7 | 16.7             |
| 16  | Total phosphates         | ppm     | 0.5                         | > 0.5                  | 16.7 | 16.7 | 16.7 | 16.7 | 16.7             |
| 17  | Ammonia (NH₃)            | ppm     | 5                           | 0.5                    | > 0.5 | 0.036 | 0.011 | 16.7 | 16.7             |

AC : The parameter accredited test NA: Not analyzed ND: Not detected

**Table 2.** Also shows the inorganic parameter of the groundwater sample.

| No. | Inorganic Parameter       | Unit(s) | Criteria for treated water | Criteria for raw water | % | Uncertainty | LOQ | LOD | Groundwater sample |
|-----|--------------------------|---------|-----------------------------|------------------------|---|-------------|-----|-----|-------------------|
| 1   | Turbidity                | NTU     | 1                           | 0.212                   | 0.152 | 3 | 2680 | 2680 |
| 2   | Electric cond.           | µS/cm   | 2.124                       | 0.80                   | 0.174 | 0.94 | 0.94 | 0.94 |
| 3   | Nitrates (NO₃)           | ppm     | 45                          | 4.4                    | 0.126 | 0.011 | 0.126 | 0.011 |
| 4   | Calcium (Ca)             | ppm     | 30                          | < 30                   | 5.3 | 0.561 | 0.155 | 0.155 |
| 5   | Sodium (Na₂CO₃)          | ppm     | 30                          | < 30                   | 5.3 | 0.561 | 0.155 | 0.155 |
| 6   | Iron (Fe)                | ppm     | 5                           | 5.0                    | 5.542 | 1.663 | 1.663 | 1.663 |
| 7   | Lead (Pb)                | ppm     | 3                           | 3.5                    | 7.398 | 2.472 | 2.472 | 2.472 |
| 8   | Magnesium (Mg)           | ppm     | 400                         | 100                    | 3.177 | 0.395 | 0.395 | 0.395 |
| 9   | Zinc (Zn)                | ppm     | 10000                       | 500                    | 5.116 | 0.335 | 0.335 | 0.335 |
| 10  | Total hardness           | ppm     | 10000                       | 500                    | 3.24 | 3.706 | 1.115 | 802.4 | 802.4 |
| 11  | Total hardness           | ppm     | 10000                       | 500                    | 3.24 | 3.706 | 1.115 | 802.4 | 802.4 |
| 12  | Total hardness           | ppm     | 10000                       | 500                    | 3.24 | 3.706 | 1.115 | 802.4 | 802.4 |
| 13  | Total hardness           | ppm     | 10000                       | 500                    | 3.24 | 3.706 | 1.115 | 802.4 | 802.4 |
| 14  | Total hardness           | ppm     | 10000                       | 500                    | 3.24 | 3.706 | 1.115 | 802.4 | 802.4 |
| 15  | Total hardness           | ppm     | 10000                       | 500                    | 3.24 | 3.706 | 1.115 | 802.4 | 802.4 |
| 16  | Total hardness           | ppm     | 10000                       | 500                    | 3.24 | 3.706 | 1.115 | 802.4 | 802.4 |

NAC : Not accredited NA: Not analyzed ND: Not detected NR: Not reported
Table 2. Shows the metal parameter of the groundwater sample.

| Sample Code | Parameter          | Unit | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 | Column 6 |
|-------------|--------------------|------|----------|----------|----------|----------|----------|----------|
| 1           | Arsenic (As)       | ppm  | 0.0      | 1.66     | 24.3     | NR       |          |          |
| 2           | Barium (Ba)        | ppm  | 0.0      | 0.33     | ND       |          |          |          |
| 3           | Beryllium (Be)     | ppm  | 1.0      | 0.33     | ND       |          |          |          |
| 4           | Cobalt (Co)        | ppm  | 0.1      | 1.66     | 15.99    |          |          |          |
| 5           | Copper (Cu)        | ppm  | 2000     | <1000    |          |          |          |          |
| 6           | Eluim (Li)         | ppm  | 0.5      | 0.166    | 272.5    |          |          |          |
| 7           | Sodium (Na)        | ppm  | 100      | 0.33     | 4.37     |          |          |          |
| 8           | Nickel (Ni)        | ppm  | 1.0      | 3.33     | NA       |          |          |          |
| 9           | Phosphorus (P)     | ppm  | 0.2      | 0.15     | 22.9     |          |          |          |
| 10          | Silicon (Si)       | ppm  | 0.2      | 0.66     | 5.073    |          |          |          |
| 11          | Strontium (Sr)     | ppm  | 1.0      | 0.33     | 2.231    |          |          |          |
| 12          | Tungsten (W)       | ppm  | 1.0      | 0.33     | 43.20    |          |          |          |

QA: Not analyzed  ND: Not detected  NR: Not reported

Figure 3. Shows the metal parameter of the groundwater sample.

Figure 4. Shows the XRD pattern of the limestone's sample.

Figure 5. The SEM examination of the limestone's sample surface.
Figure 6. Shows the EDAX analysis of the limestone's sample.

Figure 7. Shows the XRD analysis pattern for a mortar's sample from the limestone's ruins.
Figure 8. Shows the polarizing microscope examination for a mortar’s sample from the limestone' ruins.

Figure 9. Shows the SEM examination for a mortar’s sample from the limestone' ruins.

Figure 10. Shows the XRD analysis pattern for a sample of mud bricks ruins.
Figure 11. Shows the SEM examination for the mud bricks’ sample (800X).

Figure 12. Shows the EDAX analysis of the mud bricks’ sample.

Figure 13. Shows the XRD analysis pattern for a sample of the salts flakes.
Figure 14. Shows the examination of the salts flakes’ sample with SEM (800X).

Figure 15. Shows the EDAX analysis of the salts flakes’ sample.

Figure 16. Shows an overview of Sarabium’s archaeological site.

Figure 17. Shows the wide growth of weeds in limestone coffin’s area in the site.
3. Results and Discussion

- The groundwater's type in Atfiyah's Sarabium Archaeological site is Agriculture waste water due to the existence of sulphates and chlorides with high percentages, also the existence of coliform bacteria which live in the wet soils with high contamination, site is very near to the fields (100 meter far approx.) and the site is lower than the surrounding area, the agriculture waste water aggregates in the most lower point in the archaeological site (limestone' coffins).
- The limestone's sample contains calcite (Calcium carbonates) (the main component with 70 %), hydrous calcium sulphates (8%), quartz (Silicon dioxide 9%) and sodium chloride 13%), and the examination with scanning electron microscope shows the weakness of the surface.
- The source of the high percentage of salts in the limestone's sample (Sodium chloride 13% and hydrous
The identification of the Microbiological effect of the groundwater shows the existence of blue green algae (Cyanobacteria) and diatoms (Bacillariophyceae) in the water, the transmission and growth of these microorganisms in the limestone's coffins and ruins surface, the blue green algae and diatoms grow in the existence of sunlight to make photosynthesis.

• The organic activity of the algae consist biofilm which deforms the limestone's view by their stains, also the algae fix the carbon and provide a source of nutrition for heterotrophic microorganisms which may further degrade the stone's surface (bio weathering of the stones) [2], Figure (20-27).

Figure 20. Shows the blue green algae under the microscope.

Figure 21. Shows the diatoms under the microscope.

Figure 22. Shows Atfiyah's Sarabium archaeological site.
Figure 23. Shows the study area in the site (limestone' coffins and ruins).

Figure 24. Shows the agriculture waste water aggregates in one of the limestone' coffins.

Figure 25. Shows growth of salts and algae inside the limestone's coffin.

Figure 26. Shows the growth of algae on one of the limestone' ruins surface in the study area and staining of it.

Figure 27. Shows the growth of algae on the external surface of one of the limestone' coffins.

4. Conclusion

The existence of groundwater in Atfiyah's Sarabium archaeological site causes Microorganisms and salts' growth, the type of the groundwater is agriculture waste water and the resulted microorganisms' type from it (Blue green algae and diatoms) which grow widely on limestone' coffins and ruins surface, also, it causes the existence of salts (Sodium chloride and hydrous calcium sulphates) on the surface and inside the limestone. The high growth of weeds in the site also due to the existence of agricultural waste water.

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