ENVIRONMENTAL CONTAMINATION BY HEAVY METALS AND RADIOACTIVE ELEMENTS IN WADI NASAB AND ITS SURROUNDINGS, SOUTHWESTERN SINAI, EGYPT

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ABSTRACT

Wadi (Valley) Nasab (WN) and its surroundings, is an area of mining located at the southwestern Sinai, Egypt for some heavy metals and radioactive elements from Lower Carboniferous. This activity represent a source of environmental contamination. This contamination is the main target of this study. Ore material, solid wastes and soil samples were collected from 10 stations. Whereas, plants samples were collected from two types of herb weeds (i.e., Zygophyllum siplex and Haloxylon salicornicum) from WN and its surroundings southwestern of Sinai.

The original ore material is chemically consisted of around 50% SiO$_2$, 10.6% Al$_2$O$_3$, 10.2 Fe$_2$O$_3$, 13% (CaO + MgO) and around 10% loss on ignition. This figure means high carbonate and total iron contents. The mineralogic constituents of solid waste are consisted of Quartz, Kaolinite, Jarosite and Gypsum. The milling waste contains 60.2% SiO$_2$, 6.8% Al$_2$O$_3$, 9.4% Fe$_2$O$_3$, 4.7% (CaO + MgO) and 14.8% loss on ignition. The picture of some trace elements is as follow: Cu is 2900 ppm in ore materials and 359 ppm in milling waste. In the same order, Zn is 1865 and 92 ppm, Th is 14 and 5 ppm, U is 346 and 359 ppm, Ra$^{226}$ is 135 and 179 Bq/$\text{kg}$.

This picture of ore material and milling waste is reflected on the soil profile after the flash flood. The degree of contamination is pronounced in the upstream water of W. Nasab and decrease in the direction of downstream. Thorium (Th) ranged from 5 to 13 ppm at the upstream and from 4 to 5 ppm in the downstream. On the other hand, U ranged from 5 to 9 ppm in the upstream and from 2 to 7 in downstream. The contamination effect is also clear in two types of Herb weeds of WN. Uranium in roots of (Zygophyllum sipplex) plant, ranged from 4 to 6 ppm while in roots of (Haloxylon salicornicum) plant was not detected. Also, it was not detected in the vegetable parts of the two herb plants and Th was not detected in roots and the vegetable parts of the two herb plants.

Keywords: Solid waste; Heavy metals; Radioactive elements; Zygophyllum siplex; Haloxylon salicornicum

INTRODUCTION

Heavy metal pollution in soil profiles can pose dangers and hazards to human beings. Extreme concentrations of some heavy metals in biological systems, are very dangerous to human health, and may even cause death (Ayeni et al 2010). Generally, the presence of radionuclide elements (e.g., K, U, Th and Ra), as well as heavy metals (e.g., Cd, Pb and Ni), has negative effects on the environmental system, especially in agricultural soil (Abdel-Haleem et al 2001, Pulhani et al 2003, Ayeni et al 2010 and EPA, 2006).

Human beings and animals may consume radionuclides accumulated in parts of some plants in the form of food. By time, accumulation of these radionuclides within different organs of the human body may cause serious health problems if they exceed the maximum allowable dose (ICRP, 1990 and UNSCEAR, 1982 and IAEA, 1996). Moreover, 80% of the radiation dose contributes to normal radioactivity and only 20% of cosmic rays and various other nuclear processes such as radionuclides (U, Th, Ra, K, etc.).
Soil contaminated by heavy metals may cause adverse effects on plant growth. Excessive accumulation of heavy metals beyond toxic limits of plant growth in soil. The accumulation of heavy metals can lead to many distortions on plant growth such as changes in germination, leaf chlorosis or plant death (Kokkola et al. 2000, EPA, 2006, Bonnet et al. 2000 and Ayeni et al. 2010). Rumble et al. (1986), observed in their study in South Dakota, USA, that when they measured the concentrations of U and Ra elements in plants growing in the soil around the uranium mill at the study sites. These plants had higher levels of U and Ra elements compared to the control site. They also noted that the number of radionuclides absorbed by plants from the soil depends mainly on the form of radionuclides, the moisture content, and the chemical and mineral composition of the soil. Rosholt et al. (1956) and Sully et al. (1987) recommended the necessity to study the processes that transport radioactive elements and their biological activity and to study the distribution of natural radioisotopes in soil profiles. Uranium and Th are natural sources of radiation in soil minerals common in nature and absorbed on to soil components (organic matter, clays, carbonates, Fe and Mn oxides).

The danger of radionuclides for both animals, humans and plants may be very high if exposed to a maximum dose exceeding the recommended dose (ICRP, 1990, UNSCEAR, 1982, Ayeni et al. 2010 and EPA, 2006). Health problems affecting humans, possibly through direct or indirect exposure to radioactive contamination sources through different pathways, such as ingestion of contaminated water or inhalation of contact with soil contaminated or the food series (Wuana, and Okieimen, 2011). The more recent recommendation of IAEA (1996) and El Galy et al. (2008) suggested a permissible dose rate of 5 mSv/ y for members of the public and 20 mSv/ y from all natural and artificial radiation sources in the environment for work-related members.

Therefore, the study aims to assess the effect of environmental pollution of heavy elements and radioactive elements with ore materials and Solid waste in the mining area of wadi Nasab. Moreover, studying their effects on soil contamination and naturally growing herb plants.

MATERIALS AND METHODS

The purpose of this study is firstly to assess to what degree environmental contamination for some heavy metal and radioactive elements from lower Carboniferous sedimentary rocks (ore materials) and solid wastes. Secondly, assess to what degree contamination of heavy metals and radioactive materials on soil and some plants in Wadi Nasab and its surroundings.

Sampling

Ore material and solid waste samples were collected from W. Nasab and its surroundings. Soil samples were collected form 10 stations, while plant samples were collected and represented by two types herb weeds (i.e., Zygophyllum siplex and Haloxyon salicornicum) from the upstream and downstream of W. Nasab and its surroundings (as shown in Fig. 1).

Analyses

To identify the chemical composition of ore material, solid wastes and soil, a representative sample was crashed, ground to a 200 mesh grain size and the rapid analysis was applied as described by Shapiro (1975).

Mineral composition of the solid waste sample was determined by X-ray diffraction. Bulk grinding to < 2 microns, quartering and sieved sample was subjected to Philips diffract meter, the X-ray tube was a Cu target model PW 22/23. The tube was operated at 40 kV and 20 mA. The obtained diffractograms are properly interpreted using standard diffraction mineral patterns XRD as well as the model mineralogical composition was calculated sample according to Griffin (1967).

Total heavy metals, namely Zn, Mn, Pb, Ni, and Cu, were measured using a Unicam atomic absorption spectrophotometer model-969 (AAS) according to the method described by Welz and Sperling (1999), at flame type of 213.9, 279.5, 217, 232, and 324.8 nm respectively.

Total REEs and Th, were determined by UV-VIS spectrophotometer (Shimadzu UV-160) using arsenazo (III) (Marczenko, 1976) at 660 nm. Finally, for U an oxidimetric titration was used against ammonium metavanadate in the presence of diphenylamine sulphonate indicator was used. Prior to titration proper reduction was performed using ammonium ferrous sulphate as described by Mahmoud (2003).

Electrical conductivity (EC) was determined in the extract of soil paste using electrical conductivity bridge according to the method of Richards (1954).

AUJASCI, Arab Univ. J. Agric. Sci., 27(4), 2019
Chloride was determined volumetrically using silver nitrate method. Soluble sulfate was precipitated quantitatively with BCl$_2$ then excess B$_2^+$ was titrated with Na$_2$ EDTA as mentioned by Jackson (1958).

**RESULTS AND DISCUSSION**

**Specification of the solid waste and ore material**

**a- Mineralogy of solid waste**

The minerals constituent of the collected mixed waste sample from processed radioactive materials after processing with acidified water and then analyzed by X-ray diffraction (XRD) and Emission Scanning Electron Microscopy (ESEM) techniques. The mineral constituents of the solid waste under study is shown in (Fig. 2). This figure shows XRD patterns of Quartz SiO$_2$, Kaolinite Al$_4$(Si$_4$O$_{10})$(OH)$_8$, Jarosite KFe$_3^+$ (SO$_4$)$_2$(OH)$_6$ and Gypsum CaSO$_4$.2H$_2$O.

**b- Chemical characteristics of the original ore materials and solid waste**

Data in Table (1) show the chemical composition of the original ore material from lower Carboniferous sedimentary rocks and solid waste. The main component of major elements in ore material were SiO$_2$ and Al$_2$O$_3$ (50% and 10.6%), whereas the lowest major elements were MnO (0.38%), TiO$_2$ (0.51%) and P$_2$O$_5$ (0.6%). Besides, Fe$_2$O$_3$ (10.2%), (CaO + MgO) (13.9%), Alkalies as Na$_2$O was 1.4% and K$_2$O was 1.3%, chloride presented 0.76% and 9.8% of loss on ignition. This figure means high carbonate and total iron contents. The main component of major elements in the milling solid waste were SiO$_2$ (60.2%) and FeO$_3$ (9.4%).
$2\theta = \text{Angle of diffraction} \quad Q = \text{Quartz} \quad K = \text{Kaolinite} \quad G = \text{Gypsum} \quad J = \text{Jarosite}$

**Fig. 2.** XRD pattern of solid waste from the studied area

**Table 1.** Chemical composition of original ore material and solid wastes from processed radioactive materials of studied Alouga area.

| Major components | Concentration (%) | Heavy and radioactive element | Concentration (ppm) |
|------------------|-------------------|-------------------------------|---------------------|
|                  | Ore material      | Solid waste                   | Ore material        | Solid waste                  |
| SiO$_2$          | 49.80             | 60.2                          | V                   | 350                            | 89                |
| TiO$_2$          | 0.51              | 0.20                          | Cu                  | 2900                           | 359               |
| Al$_2$O$_3$      | 10.60             | 6.82                          | Cd                  | 22                             | 7                 |
| Fe$_2$O$_3$      | 10.20             | 9.42                          | Zn                  | 1865                           | 92.4              |
| MnO              | 0.38              | 0.23                          | Mn                  | 3746                           | 3144              |
| CaO              | 7.46              | 1.48                          | Pb                  | 400                            | 305               |
| MgO              | 5.52              | 3.2                           | Ni                  | 320                            | 186               |
| Na$_2$O          | 1.40              | 0.32                          | CO                  | 250                            | 126               |
| K$_2$O           | 1.32              | 0.56                          | REEs                | 810                            | 561               |
| P$_2$O$_5$       | 0.60              | 0.32                          | U                   | 346                            | 184               |
| L.O.I.           | 9.8               | 14.8                          | Th                  | 14                             | 26                |
|                  |                   |                               | K                   | 18                             | 11                |
| **Total**        | **98.35**         | **97.58**                     | **Ra**              | *135                           | *179              |

* = Bq/ kg
Whereas it was (4.7%) for (MgO + CaO). In addition, alkalies were Na2O (0.3%), K2O (0.5%), chloride presented (0.76%) and (14.8%) for loss on ignition (Table 1). This figure indicates high total iron content in the ore material.

Data in the same table show the main trace elements of the original ore material and solid waste. The main trace elements in ore material were Mn (3746 ppm), Cu (2900 ppm) and Zn (1865 ppm). The main trace elements in the milling solid waste were Mn (3144 ppm) and (REEs 561 ppm). Thorium recorded 14 ppm in ore material and 26 ppm in the milling waste respectively, while U record 346 ppm in the ore material and 184 ppm in the milling waste, and Ra226 has 135 Bq/kg in the ore material and 179 Bq/kg in the milling waste. This table showed increase of solubility with acidified water used in leaching ore materials for V, Cu, Zn and U, while Mn, Pb and Ni showed decrease in solubility.

Chemical characteristics of soil

The ore material and milling waste are subjected every year to the flash flood at days 11 to 16 of December (Fig. 3). 

The chemical composition of the studied soil profiles is shown in (Table 2). The collected samples represent the upstream soil profile named Ag.S1, Ag.S2, Ag.S3, Ag.S4 and Ag.S5. The collected downstream soil samples are Ns.S1, Ns.S2, Ns.S3, Ns.S4 and Ns.S5 which collected from W. Nasab area. The values of SiO2 concentration in the upstream soil profiles are ranged between 58.3 and 62.5% while, Al2O3 between 9.89 and 12.23%, Fe2O3 ranged between 6.65% and 11.5%. In the downstream the SiO2 ranged between 57.8% and 66.5%. Aluminum oxide (Al2O3) ranged between 11.3% and 17.23%, Fe2O3 ranged between 5.25% and 9.58%. The loss on ignition ranged between 7.92% and 9.26% in downstream soil sediments and between 8.84% and 11.52% in the upstream. Trace elements distribution (Table 3) in the upstream soil profile showed that Cu ranged between 2048 and 3637 ppm, while Zn ranged between 173 and 442 and REEs ranged from 8 and 26 ppm, while U ranged between 3 and 9 ppm, also, Th ranged between 4 and 13 ppm. The picture of some trace elements in the downstream soil profile is different as the Cu ranged between 1464 and 2168 ppm, while Zn ranged between 130 and 374 ppm, REEs ranged between 4 and 14 ppm, while U ranged between 2 and 5 ppm, and Th ranged between 4 and 7 ppm. From the previous data, it is noticed that the distribution of major and trace elements decreased from upstream to downstream when can be due to the annual flash floods.

It is evident from the results that the concentrations of Cu, Cd, Zn, Mn, Pb and Ni are above phytotoxic limits in all soil samples taken from the soil profiles in W. Nasab and its surroundings. This may lead to abnormalities in the germination process of some plants or death of plants as was explained by Kukkola et al (2000), Bonnet et al (2000) and Ayeni et al (2010). Also, the results of measurement of radioactive elements in different soil samples of study area indicate U and Th at levels higher than those mentioned by International Standard Dose Rate Unit and plant life which is 1 Sv/kg (Knoll 2000).

Contamination of the Herb weeds plants by heavy metals and radioactive elements

The two studied types of plants which recorded in course of W. Nasab from Upstream (Zygophyllum siplex) species to the downstream (Haloxylon salicornium) species are shown in (Fig. 4).

Uranium in roots of Zygophyllum siplex ranged from 4 to 6 ppm and there is no contamination found in the vegetable growth, while in Haloxylon salicornium species there is contamination in both roots and vegetable parts. In contrast, Th was not detected in roots and the vegetable parts of the two herb plants. However, this accumulation can be effective on the long run.

No contamination by Cu was found in both roots and vegetable parts in the two plants as shown in (Tables 4 and 5). On the other hand, there is variable concentration of different trace elements in both types of plants. On the other hand, Cd, Zn, Mn, Pb and Ni elements were found in soil profiles beyond those causing harm to the two herbs (Abdel-Haleem et al 2001, Pulhani et al 2003, Ayeni et al 2010 and EPA, 2006). This means that these two herbs can accumulate heavy elements, and hence can be used for soil phytoremediation.
Fig. 3. Start of flash flood at Alouga and the look at downstream of W. Nasab.

Table 2. Chemical analyses of major components in soil profiles of W. Nasab and Alouga area

| Component major | Concentration in different soil profiles (%) |
|-----------------|---------------------------------------------|
|                 | Ag.S1 | Ag.S2 | Ag.S3 | Ag.S4 | Ag.S5 | Ns.S1 | Ns.S2 | Ns.S3 | Ns.S4 | Ns.S5 |
| SiO₂            | 58.33 | 61.95 | 62.5  | 62.3  | 58.66 | 57.8  | 59.65 | 66.5  | 62.60 | 62.67 |
| TiO₂            | 0.10  | 0.11  | 0.09  | 0.07  | 0.07  | 0.10  | 0.15  | 0.09  | 0.09  | 0.12  |
| Al₂O₃           | 12.23 | 10.15 | 9.89  | 11.45 | 10.6  | 17.23 | 12.80 | 11.30 | 12.10 | 13.25 |
| Fe₂O₃           | 9.44  | 8.65  | 11.2  | 6.65  | 11.5  | 9.50  | 7.50  | 5.25  | 9.58  | 8.65  |
| MnO             | 0.28  | 0.35  | 0.19  | 0.12  | 0.84  | 0.13  | 0.09  | 0.56  | 0.08  | 0.24  |
| CaO             | 1.95  | 2.55  | 3.33  | 3.45  | 2.95  | 1.50  | 3.10  | 1.90  | 2.30  | 2.35  |
| MgO             | 2.86  | 2.0   | 1.95  | 2.33  | 2.10  | 2.30  | 1.80  | 1.10  | 1.90  | 2.50  |
| Na₂O            | 0.02  | 0.04  | 0.10  | 0.20  | 0.10  | 0.12  | 0.25  | 0.19  | 0.09  | 0.18  |
| K₂O             | 0.32  | 0.12  | 0.14  | 0.35  | 0.09  | 0.11  | 0.34  | 0.22  | 0.14  | 0.16  |
| P₂O₅            | 0.30  | 0.01  | 0.08  | 0.06  | 0.07  | 0.09  | 0.10  | 0.04  | 0.08  | 0.03  |
| Cl⁻             | 0.36  | 0.23  | 0.33  | 0.37  | 0.30  | 0.32  | 0.28  | 0.28  | 0.22  | 0.34  |
| L.O.I.          | 11.52 | 10.51 | 8.84  | 9.46  | 9.21  | 8.92  | 9.56  | 8.76  | 8.43  | 7.92  |
| Total           | 97.71 | 96.67 | 98.28 | 96.81 | 96.44 | 98.12 | 95.62 | 96.19 | 97.61 | 98.41 |
Table 3. Chemical analyses of heavy metal and radioactive elements from soil of W. Nasseib and Alluga area

| Heavy and radioactive elements | Concentration in different soil profiles (ppm) | Upstream | Downstream |
|-------------------------------|-----------------------------------------------|----------|------------|
|                               |                                               | Ag.S1    | Ag.S2 | Ag.S3 | Ag.S4 | Ag.S5 | Ns.S1 | Ns.S2 | Ns.S3 | Ns.S4 | Ns.S5 |
| Cu                            |                                               | 3637     | 2220  | 2048  | 2484  | 2484  | 1776  | 1706  | 2208  | 1464  | 2168  |
| Cd                            |                                               | 8        | 5     | 6     | 5     | 12    | 9     | 9     | 4     | 6     | 8     |
| Zn                            |                                               | 442      | 186   | 173   | 280   | 192   | 148   | 265   | 374   | 142   | 130   |
| Mn                            |                                               | 4702     | 2688  | 1213  | 1343  | 1804  | 949   | 422   | 1153  | 435   | 625   |
| Co                            |                                               | 71       | 154   | 178   | 68    | 70    | 54    | 50    | 62    | 41    | 52    |
| Pb                            |                                               | 189      | 287   | 239   | 258   | 224   | 202   | 164   | 194   | 148   | 156   |
| Ni                            |                                               | 196      | 257   | 230   | 216   | 179   | 177   | 144   | 130   | 184   | 140   |
| REEs                          |                                               | 26       | 16    | 12    | 16    | 8     | 14    | 4     | 10    | 10    | 8     |
| U                             |                                               | 9        | 9     | 7     | 7     | 3     | 5     | 5     | 5     | 2     | 2     |
| Th                            |                                               | 13       | 13    | 5     | 4     | 4     | 7     | 5     | 4     | 4     | 5     |

* Alluga area. ** W. Nasab area.

Fig. 4. Herb weeds of W. Nasab and its surrounding areas.
Table 4. Chemical analyses of heavy metals and radioactive elements in *Zygophyllum simplex* species

| Heavy and radioactive elements | Concentration in *Zygophyllum simplex* species (ppm) |  |  |  |  |  |  |  |  |
|-------------------------------|---------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                               | Roots (Z1/R)                                | Vegetable parts | Roots (Z1/V)    | Vegetable parts | Roots (Z2/R)    | Vegetable parts | Roots (Z2/V)    | Vegetable parts | Roots (Z3/R)    | Vegetable parts | Roots (Z3/V)    | Vegetable parts |
| Cu                            | n.d                                         | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             |
| Cd                            | 2                                            | 2               | 2               | 5               | 5               | 0.5             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             |
| Zn                            | 163                                          | 170             | 148             | 132             | 128             | 74              | 81              | 18              | 44              | 49              | 49              | 49              |
| Mn                            | 198                                          | 124             | 154             | 180             | 159             | 85              | 52              | 65              | 50              | 115             | 115             | 115             |
| Co                            | 76                                           | 77              | 66              | 52              | 96              | 41              | 52              | 47              | 47              | 47              | 47              | 47              |
| Pb                            | 220                                          | 179             | 181             | 196             | 186             | 119             | n.d             | 108             | 170             | 54              | 54              | 54              |
| Ni                            | 52                                           | 42              | 38              | 30              | 101             | 10              | n.d             | n.d             | n.d             | 21              | 21              | 21              |
| U                             | 6                                            | 5               | 4               | 4               | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             |
| Th                            | n.d                                          | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             |

(n.d) = not detected.

Table 5. Chemical analyses of heavy metals and radioactive elements in *Haloxylon salicornicum* species

| Heavy and radioactive element | Concentration in *Haloxylon salicornicum* species (ppm) |  |  |  |  |  |  |  |  |  |  |  |
|-------------------------------|-----------------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                               | Roots (H1/R)                                        | Vegetable parts | Roots (H1/V)    | Vegetable parts | Roots (H2/R)    | Vegetable parts | Roots (H2/V)    | Vegetable parts | Roots (H3/R)    | Vegetable parts | Roots (H3/V)    | Vegetable parts |
| Cu                            | n.d                                                  | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             |
| Cd                            | 4                                                     | 3               | 4               | 5               | 5               | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             |
| Zn                            | 170                                                   | 121             | 215             | 97              | 145             | 90              | 24              | 64              | 43              | 42              | 42              | 42              |
| Mn                            | 215                                                   | 192             | 302             | 217             | 366             | 92              | 145             | 119             | 112             | 145             | 145             | 145             |
| Co                            | 54                                                     | 27              | 29              | 47              | 71              | 39              | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             |
| Pb                            | 168                                                   | 116             | 89              | 100             | 93              | 34              | 60              | 86              | 47              | 45              | 45              | 45              |
| Ni                            | 111                                                   | 181             | 105             | 149             | 70              | 59              | n.d             | n.d             | 47              | n.d             | n.d             | n.d             |
| U                             | n.d                                                   | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             |
| Th                            | n.d                                                   | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             | n.d             |

(n.d) = not detected.

**CONCLUSION**

From the previous complementary work for ore material, milling waste, soil and plants, it can be conceded that the activities in this location led to pollution in the soil by some heavy metals and radioactive elements. One of the positive results from this study is the action of *Zygophyllum simplex* plant in accumulating some of heavy metals and radioactive elements in its roots. In contrast, *Haloxylon salicornicum* did not accumulate, any of them. Hence, it is recommended to achieve more experiments on the ability of other types of plants in phytoremediation after chemical retreatment for milling solid waste.

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[187]

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الموجز

وادي نصب من أحد المناطق المحيطة بمنطقة تعدين المعادن الثقيلة والمشعة من الصخور الرسوبية منخفضة الرتبة ويمثل هذا النشاط مصدرًا للتلوث البيئي ودراسة تأثير هذا التلوث هوهدف رئيسي من هذه الدراسة. تم تجميع المادة الخام والمخلفات الصلبة وعينات الطربة من 10 مواقع مختلفة وجمع عينات [Zygophyllum siplex] و [Haloxylon salicornicum] من وادي نصب ومحيطه في جنوب غرب سيناء. تحتوي المادة الخام على عدد من المكونات الكيميائية هي أكاسيد السليكا (50%)، الألومنيوم (10.6%)، الحديد (10.2%)، الكالسيوم والمغنسيوم (13%)، والثوريوم والكالسيت وتحتوي أيضاً على أكاسيد السليكا (60.2%) والألومنيوم (6.8%)، الحديد (9.4%)، والكالسيوم والمغنيسيوم (13%)، والثوريوم والكالسيت وتحتوي أيضاً على أكاسيد السليكا (50%)، الألومنيوم (10.6%)، الحديد (10.2%)، الكالسيوم والمغنسيوم (13%)، والثوريوم والكالسيت وتحتوي أيضاً على أكاسيد السليكا (60.2%) والألومنيوم (6.8%)، الحديد (9.4%)، والكالسيوم والمغنيسيوم (13%)، والثوريوم والكالسيت وتحتوي أيضاً على أكاسيد السليكا (50%)، الألومنيوم (10.6%)، الحديد (10.2%)، الكالسيوم والمغنسيوم (13%)، 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