INTERNATIONAL JOURNAL OF LATEST TECHNOLOGY IN ENGINEERING, MANAGEMENT & APPLIED SCIENCE (IJLTEMAS)
ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue X, October 2025

# Assessment of $^{39}$K, $^{232}$Th, and $^{238}$U isotopes in soil samples with ICP-MS in El-Obied, Sudan

**Amar Belly[1,2], Abdelrazig M. Abdelbagi[3,4] Abdelaziz A.M. El Shokali1[3], Ahmed Elfaki[1]**

**[1]Physics Department, College of Science, Sudan University for Science and Technology, Khartoum, Sudan**

**[2]University of Sennar, Physics Department, Education College, Sennar, Sudan**

**[3]Physics Department, College of Science and Humanities, Al-Dawadmi, Shaqra University, Riyadh, KSA**

**[4]Omdurman Islamic University, Faculty of Science, Omdurman, Sudan**

**DOI: https://doi.org/10.51583/IJLTEMAS.2025.1410000120**

**Received: 02 November 2025; Accepted: 08 November 2025; Published: 17 November 2025**

**Abstract:** The main objective of the present study was to determine the concentrations of the radioisotopes potassium-$^{39}$K, thorium-$^{232}$Th, and uranium-$^{238}$U in soil samples collected from selected areas around El-Obeid City, Sudan. Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) analysis was employed to quantify these isotopes. Soil samples were obtained from five locations surrounding El-Obeid, specifically from two regions in the southern and western parts of the city within North Kordofan State, in areas located away from residential zones. High correlation coefficients between $^{232}$Th and $^{238}$U indicate that these isotopes likely originate from the same source. Principal component and factor analyses further confirm that $^{232}$Th and $^{238}$U share common sources in the soil samples collected from various locations around El-Obeid City. In addition, the measured concentrations of $^{238}$U and $^{39}$K are in reasonable agreement with values reported in the literature. The concentration of $^{232}$Th observed in this study is relatively high compared to values reported from other regions worldwide, suggesting possible local geological or anthropogenic influences.

**Keyword:** Radioactive elements, Potassium; Thorium; Uranium; ICP_MS spectrometer, Data Analysis, Elobied, Sudan

## I. Introduction:

Natural terrestrial background radiation in the environment originates from various sources, including gamma, alpha, and beta radiation emitted by naturally occurring radionuclides found in soil, rocks, water, and air. The natural terrestrial background radiation primarily comes from naturally occurring radionuclides in the Earth's crust, soil, and atmosphere (1). These originate from radioactive elements present in the soil, rocks, and building materials (2). The level of environmental radiation pollution provides essential radiological information on radiation levels in soils, building materials, water, food, and air. Uranium is the most abundant naturally occurring element, which is primordially radioactive and decays until it reaches a stable nucleus (3).

Moreover, uranium in the earth's crust is mainly found in soil, beach sand, and rocks, with the highest concentration in phosphate rocks, which represent an estimated abundance of 0.5 to 5 ppm. A significant natural radionuclide found in the Earth's crust is the uranium isotope (4). After decaying into thirteen radioactive daughter isotopes and emitting alpha radiation, the parent atom 238U eventually becomes stable lead ($^{206}$Pb). Uranium-238 is the most abundant of the three natural uranium origins in the Earth's crust and is an important radionuclide since Earth's formation, continuously emitting alpha radiation (5). Uranium can be leached from source rocks and redeposited in reducing environments such as sandstones, clays, and organic-rich layers. Concentrations are usually lower unless secondary enrichment occurs. Two isotopes of uranium, uranium-$^{238}$U, are found (6). The province under study, located within the uranium province district, aligns with the geological features typical of sub-Saharan African countries where uranium ore has been discovered. The natural presence of uranium in soil and human activities are the main sources of trace levels of uranium in the human environment. Both natural and external sources of irradiation emit gamma radiation (7). Terrestrial environmental radiation, which originates from naturally occurring radioactive elements in the Earth's crust, can indeed have negative impacts on both the environment and human health (8). An essential step in assessing the radiation dose exposure to individuals in the area, as a basis for the environmental pollution from $^{39}$K, $^{232}$Th, and $^{238}$U radioactive sources, is determining the natural radioactivity of the elements in the soil in the study district (9). Potassium is an abundant element essential to life, and $^{39}$K is found in the Earth's crustal rock in three isotopes: $^{39}$K, $^{40}$K, and $^{41}$K. Potassium-39 (K-39) is a stable isotope that naturally occurs in soil, typically at concentrations ranging from 1 to 2 milligrams per kilogram (ppm) (10). This isotope contributes to the overall potassium content in geological materials but is not radiogenic. The stable isotope 39K constitutes 93.258% of the total of potassium isotopes in nature. (Steno Wang; Morgan et al., 2018).

In the Earth's crust, thorium is frequently found in the thorium-phosphate minerals, which can contain up to 12% thorium oxide, $ThO_2$. Since thorium is likewise radioactive, the parent isotope's typical decay cycle results, and many of the daughters are gamma emitters. The predominant isotope, thorium-232, is a naturally occurring radioactive metal that is concentrated mainly in acidic igneous rocks such as granites. Also, the average thorium concentration is 16.19 ppm (11).

Assessing the natural radioactivity in the soil of the study area is a critical step in evaluating the potential radiation dose to human exposure. This assessment provides a scientific basis for understanding the extent of environmental pollution arising from naturally

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue X, October 2025

occurring radioactive materials, particularly $^{39}K$, $^{32}Th$, and $^{238}U$**.** Monitoring naturally occurring radionuclides in the environment is essential for accurate radiological risk evaluation and effective long-term environmental health management (12).

**Study Area:**

El-Obeid, located in central-western Sudan, is the capital of North Kordofan State. Its approximate geographical coordinates are 13°11′ N, the latitude, and 30°13′ E. El-Obeid is situated within the semi-arid Sahel region, not far from the border between North and South Kordofan, and is distinct from Sudan's Eastern Desert, which lies much farther east (9). The western and southern regions of El Obeid are primarily composed of sand and sediment. A total of thirty-seven (37) soil samples were collected from various locations throughout the province, including sites near residential. The Eastern Desert lies to the east of the Nile, while El Obeid is well to the west, in the Sahelian belt of central-western Sudan. The region around El Obeid experiences a semi-arid**.** In terms of natural resources, five zones have been identified in the area for their sample collections**.** The surrounding area shows extensive agricultural cultivation and animal husbandry, highlighting the city's deep connection to the land. These activities are crucial not only for subsistence and the local economy but also serve as a fundamental aspect of the native cultural identity within the region. The zones' qualitative analysis of samples from selected locations indicated promising elemental signatures, suggesting the potential radioactive enrichment that warrants further investigation. The qualitative analyses of samples from chosen locations revealed encouraging elemental signatures, indicating the potential radioactive enrichment, which requires further examination.

Experimental and Methods:

Soil samples were collected from five sites located around El-Obied City in western Sudan. These sites were selected to evaluate trace elements in the local environment. Due to the nature of the samples, soil extracted from the underground area at a depth of 0.5 meters can be analyzed with minimal or no pretreatment. Inductively Coupled Plasma Mass Spectrometry ICP-MS is a highly sensitive and precise technique for detecting trace and ultra-trace elements across a wide range of scientific fields (13). The capability to measure both concentrations and low detection limits makes it a go-to method in environmental and nuclear sciences. In this study, the concentration of trace elements in soil samples was measured using ICP-MS at the Atomic Energy Authority Nuclear Research Center, Center Laboratory for Elemental and Isotopic Analysis, Cairo, Egypt. Inductively Coupled Plasma Mass Spectrometry was employed for precise concentration measurements, aiding in the exploration of the isotopic analysis of elements. In this study, the analysis focused on the radioactive elements Potassium ($^{39}K$), Uranium ($^{238}U$), and Thorium ($^{232}Th$).

## II. Results and Discussion:

The preliminary outcomes of the study highlighted the value of using ICP-MS to detect potassium, thorium, and uranium**,** as well as for assessing the spatial distribution of other elements in the area. The resulting data were subjected to various assessment methods and statistical analyses to ensure accuracy, reliability, and meaningful interpretation of the elemental concentrations. Samples are typically prepared in a soluble form for accurate analysis. Qualitative analysis of the soil samples indicated the presence of $^{39}K$, $^{232}Th$, and $^{238}U$, with the corresponding peak concentrations presented in Figure 1. Distribution patterns, particularly of uranium multiplied by 1000 at the value, appear in the graph of the soil samples collected from the Elobied, Sudan. Figure 2 displays the factor analysis distribution of nuclear isotope concentration values, indicating that $^{232}Th$ and $^{238}U$ varied across all samples and were different from $^{39}K$. The factors of variable concentration in one part of the graph, and the factors of variable $^{232}Th$ and $^{238}U$ from similar sources in all sites.

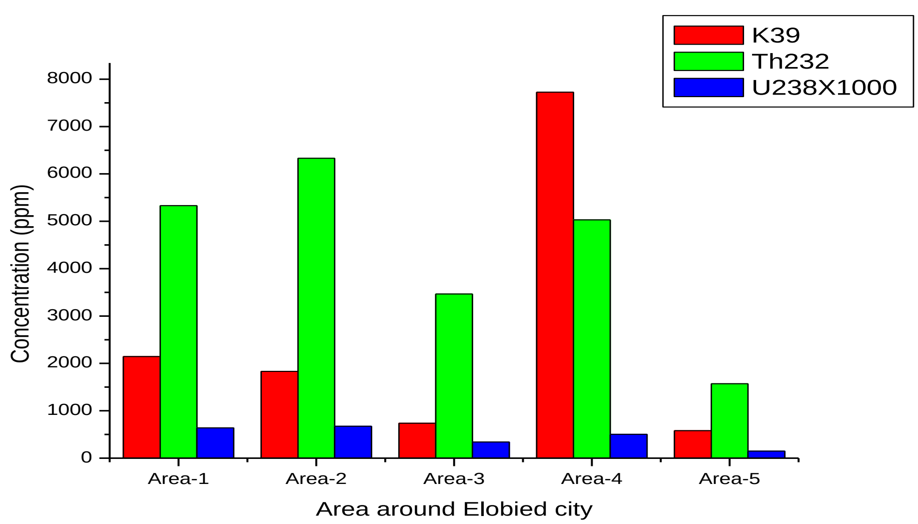


Fig. 1 Average radionuclide element concentration in Elobied.

INTERNATIONAL JOURNAL OF LATEST TECHNOLOGY IN ENGINEERING, MANAGEMENT & APPLIED SCIENCE (IJLTEMAS)
ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue X, October 2025

Table 1: Correlation is significant at the 0.01 level.

| Isotopes | $^{39}K$ | $^{232}Th$ | $^{238}U$ |
|---|---|---|---|
| $^{39}K$ | 1 | .401 | .319 |
| $^{232}Th$ | .401 | 1 | .983** |
| $^{238}U$ | .319 | .983** | 1 |

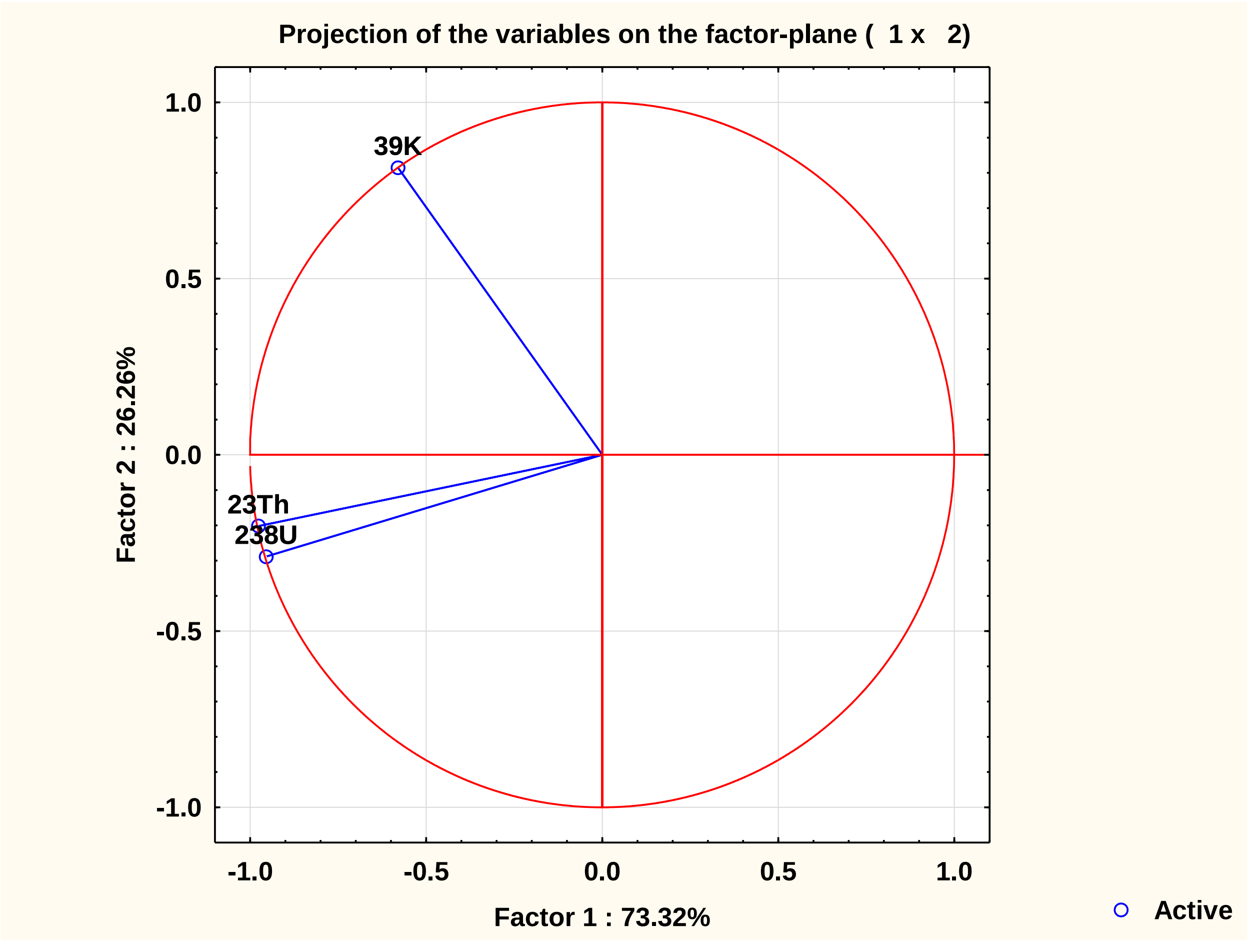


Figure 2: The Factor Analysis Distribution of Nuclear Isotope Concentration Values.

Table 2: t-test of the location

| Element<br>Isotope | Area-1 | Area-2 | Area-3 | Area-4 | Area-5 |
|---|---|---|---|---|---|
| | t | T | t | t | t |
| 39K | 5.601 | 4.251 | 10.369 | 7.148 | 4.064 |
| 232Th | 6.185 | 8.142 | 5.323 | 7.556 | 10.425 |
| 238U | 5.595 | 7.584 | 4.524 | 7.561 | 13.499 |

Table 3: Factor Analysis

| Extraction Method: | | Principal Component Analysis |
|---|---|---|
| | Location east ELobied | Location south Elobied |

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue X, October 2025

| Isotopes elements | Communalities Extraction | Component Matrix [a] | Communalities Extraction | Component Matrix [a] |
|---|---|---|---|---|
| $^{39}K$ | .013 | .113 | .317 | .563 |
| $^{232}Th$ | .918 | .958 | .853 | .924 |
| $^{238}U$ | .920 | .959 | .873 | .935 |

Table 4. International reference data on the soil.

| Region | Th(ppm) | U(ppm) | K (%) | Reference |
|---|---|---|---|---|
| IAEA-326-soil-Reference | 9.71 | 2.38 | 1.91 | Bajanowki-2001 |
| United state | 8.9±4.2 | 3.0± 2.5 | - | Myrick et al 1983 |
| Amman, Jordan | 7.1 | 4.6 | 1.7 | Ahmed et al(1997) |
| Istanbul, Turkey | 9.1 | 1.7 | 1.1 | Karahan and Bayulken-(2000) |
| Coastal area, Greece | 17.5±6.2 | 7.5± 3.5 | 2.9 ± 1.2 | Florouand Kritidis (1992) |
| Taiwan | 10.8 | 2.4 | 1.4 | Yu.Ming et al (1987) |
| Italy | 18-21 | 4.6- 5.7 | 1.9 – 2.5 | Bellia et al (1997) |
| Spain | 3.2-20.9 | 1.6-57.6 | 1.0-2.3 | Martinez-Aguirre and Garcia-Leon. 1992) |
| Rajasthan India | 10.6- 26.1 | 2.4-6.3 | 0.2-0.5 | Nageswara et al (1996) |
| Worldwide average | 7.4 | 2.8 | 1.3 | UNSCEAR report (2000) |
| El Obied, Sudan | 1572.2-6331.47 | 0.1499-0.6741 | 0.0581- 0.7723 | Present study |
| | | | | |

## III. Discussion

The results of the soil analysis from the collected samples in the province under study, conducted using an ICP-MS spectrometer, are presented in the accompanying graph. Among the samples, the soil from **El-obeid** shows the highest concentrations of $^{232}Th$ and $^{39}K$. The graphical representation highlights factors contributing to concentration variability, with $^{232}Th$ and $^{238}U$ displaying similar distribution patterns, suggesting a common source is based on their relative percentage variations across all sampling sites. Table 1 shows the correlation coefficients among the element concentrations of these isotopes across the different sampling locations. The observed data suggest a direct relationship between $^{232}Th$ and $^{238}U$ concentrations, whereas $^{39}K$ shows notable variations among the study areas, reflecting differences in soil composition or mineral content (14). The results are summarized in Table 2**,** which presents the t-test values for the elements $^{39}K$, $^{232}Th$, and $^{238}U$ in soil samples collected from the five study sites, indicating identical values for $^{232}Th$ and $^{238}U$. Table 3 presents the results of the principal component analysis (PCA), including the communalities extraction and component matrix for the isotopes $^{39}K$, $^{232}Th$, and $^{238}U$ in soil samples collected from two locations, the western and southern sites of El-Obied. The communalities extraction and component matrix values for $^{232}Th$ and $^{238}U$ show almost identical results across the sites, with noticeable differences observed for $^{39}K$ in the area (15). Table 4 presents international reference data on soil alongside the average results from this study, which were obtained from locations characterized by lower $^{238}U$ concentrations, $^{39}K$ values within a similar percentage range, and higher $^{232}Th$ levels.

## IV. Conclusion:

This study presents the first evaluation of the concentrations of the radioactive isotopes $^{39}K$, $^{232}Th$, and $^{238}U$ in soil samples collected from various locations around Elobied, Sudan. The investigation detected the isotopes in a province surrounding Elobied city, located in North Kordofan State, Sudan, in areas situated away from residential zones. A significant difference in the concentrations of thorium $^{232}Th$ and uranium $^{238}U$ was observed; however, statistical analyses, including principal component analysis (PCA) and factor analysis, indicated that a considerable portion of the data exhibited nearly constant values. The uranium $^{238}U$ concentration obtained in this study was lower than the international reference values presented in Table 4 and those reported by UNSCEAR (2000). In contrast, the concentration of $^{232}Th$ was relatively high in all 37 soil samples collected from the five study areas, compared with international reference data. Furthermore, the $^{39}K$ concentration exceeded the optimum level; however, the total potassium

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue X, October 2025

values remained within acceptable limits when compared to global reference data from previous studies (Table 4). Moreover, the findings of this study provide a valuable baseline for future environmental monitoring and research in the region. These results, particularly the elevated levels of thorium, highlight the critical importance of establishing local guidelines and regulatory policies to accurately assess and mitigate the risks associated with heavy metal exposure.

**Acknowledgment:** The author(s) gratefully acknowledge the Atomic Energy Authority Nuclear Research Center, Center Laboratory for Elemental and Isotopic Analysis, Cairo, Egypt, which provided the ICP_MS facilities and equipment. support for this research.

**References:**

1. A.D. Bajoga [a b], N. Alazemi [a c], P.H. Regan [a d], D.A. Bradley [a e], Radioactive investigation of NORM samples from Southern Kuwait soil using high-resolution gamma-ray spectroscopy, Radiation Physics and Chemistry, Volume 116, November 2015, pp. 305-311, https://www.sciencedirect.com/science/article/pii/S0969806X15000481
2. Anaheed Ahmed 1, Thaer M Salman, Mostafa A Algrifi,, The Concentration of Uranium-238 in Soil Samples from the Central Maysan Governorate Determined Using ICP-MS, Health Phys, the radiation safety journal,2024 Nov 1;127(5):565-568. DOI: 10.1097/HP.0000000000001846
3. Mostafa A. Algrifi, Thaer M. Salman, Measuring uranium concentration in Um Qasr district, southern Iraq, in two different ways, Applied Radiation and Isotopes Volume 192, February 2023, 110595. https://doi.org/10.1016/j.apradiso.2022.110595
4. Hussain A.M. Al-Trabulsy a, Ashraf E.M. Khater a b, Farouq I. Habbani c, Heavy elements concentrations, physicochemical characteristics, and natural radionuclides levels along the Saudi coastline of the Gulf of Aqaba, Published in Arabian Journal of Chemistry (2013), Volume 6, Issue 2, Pages 183–189, https://doi.org/10.1016/j.arabjc.2010.10.001
5. Wenshuai Li, Xiao-Ming Liu, Kun Wang, Yoshio Takahashi, Yongfeng Hu, Soil potassium isotope composition during four million years of ecosystem development in Hawai'I, Geochimica et Cosmochimica Acta, June 2022, DOI:10.1016/j.gca.2022.06.025
6. Mehra R, K Badhan, RG Sonkawade,S Kansal and S Singh (2010).“Analysis of terrestrial natural radionuclides in soil samples and assessment of average effective dose “Indian Journal of pure and applied physics vol 48., https://nopr.niscair.res.in/bitstream/123456789/10484/1/IJPAP%2048(11)%20805808.pdf
7. Q.J. Tarbool1, S.H. Kadhim2, A.S. Alaboodi2, A.A. Abojassim2*, Assessment of environmental radioactivity in soil samples of primary schools in North of Al-Najaf governorates, International Journal of Radiation Research, April 2022, Volume 20, No 2 , pp.468-472, https://ijrr.com/article-1-4281-en.pdf
8. UNSCEAR, United Nations Scientific Committee on the effects of atomic radiation: 2000. Sources, Effects and risks of Ionizing Radiation.United Nations. NewYork.https://www.unscear.org/unscear/en/publications/2000_1.html
9. Sam. Adam, Ahmed Mustafa, El Khangi, F.A., El Nigumi, Y.O., Elis, H. (1999) Radiological and chemical assessment of Uro and Kurun rock phosphates. Journal of Environmental Radioactivity. 42, 65-75. https://www.sciencedirect.com/science/article/pii/S0265931X97000969
10. Michalis Tzortzis, Haralabos Tsertos, Determination of thorium, uranium and potassium elemental concentrations in surface soils in Cyprus, Journal of Environmental Radioactivity, Volume 77, Issue 3, 2004, Pages 325-338, https://doi.org/10.1016/j.jenvrad.2004.03.014
11. Hassan,Nur Nazihah, and Siong Khoo, Kok, (2014). Measurement of natural radioactivity and assessment of radiation hazard indices in soil samples at Pengerang, Kota Tinggi, Johor. AIP Conference Proceedings, 1584, 190. https://pubs.aip.org/aip/acp/article/1584/1/190/846360/Measurement-of-natural-radioactivity-and
12. apanadze. Kakhaber, Magalashvili, Archil, Imnadze, Platon, (2019) , Distribution of natural radionuclides in the soils and assessment of ra-diation hazards in the Khrami Late Variscan crystal massif (Georgia) Heliyon.Volume 5, Issue 3, March 2019, e01377. https://www.sciencedirect.com/science/article/pii/S2405844018367628
13. Thaer M. Salman, and Sawsan Sh. Fleifil, Evaluation of Uranium Concentration in Soil Samples of Basrah Governorates using ICP-Mass Techniques, IOSR Journal of Engineering (IOSRJEN) 2250-3021, ISSN (p): 2278-8719 Vol. 05, Issue 10 (October 2015), ||V1|| PP 43-47, http://un.uobasrah.edu.iq/papers/10744.pdf
14. Fathi M.Ibrahim A.Sergani, Abdelrazig.M.Abdelbagi, Abdelaziz A.M.ELshokali, Evaluation of Uranium, Thorium and Some Metal Elements in Rocks by HR-ICP-MS and LIBS, Journal of Nuclear Energy Science & Power Generation Technology, Volume 5, No.5, pp. 1-5, 2016, doi: 10.4172/2325-9809.1000168
15. Philip K. Hopke 1, David D. Cohen 2, Application of receptor modeling methods, Atmospheric Pollution Research Volume 2, Issue 2,, 122-125, (2011) https://doi.org/10.5094/APR.2011.016