

Investigation of depleted Uranium Contamination in Soil Samples Collected from Aden Assoghra city, Yemen

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Abstract: This study was done for assessment of Depleted Uranium (DU) contaminated surface soil in the seventeen regions in Aden Assoghra city, Yemen, Depleted Uranium (DU) is uranium with low content of ^{235}U produced as a result of uranium enrichment. DU has high density (19.05g/cm^3), which is 2.54 more than Iron, so it's high penetrating power makes it preferable as emanations with high penetration power. It was used in second Gulf war in 1991 for first time. Seventeen samples of soil were selected from different sites in Aden Assoghra city, Yemen, Radioactivity of these samples was measured using Gamma-ray Spectroscopy. Gamma-ray spectroscopy system consists of high purity germanium (HPGE) detector surrounded by appropriate shield. The measurement of detector efficiency using Genie2000 computer programs, supplied by Canberra Company was used to analyze gamma-ray spectrum. The activity of ^{234}Th , ^{235}U , ^{234}Pa and other natural isotopes were measured. The measurements show that radiation equilibrium between ^{234}Th and ^{226}Ra existed with the range between (0.88-1.1) and radiation equilibrium between ^{234}Th and Pa-234m existed with the range between (0.83 - 1.24). The measurement by gamma-ray spectrometry system showed that eleven samples were contaminated with Depleted Uranium (DU), because the presence of ^{234}Pa and ^{235}U peak and the percentage ratio between $^{235}\text{U}/^{238}\text{U}$ were less than 0.005, when the international mathematical method, namely Kosovo, were used. Because of existence of radiation equilibrium between ^{234}Th and ^{234}Pa , the measurements should be accurate. The result showed that eleven of the samples were contaminated with Depleted Uranium (DU) and there is a good agreement with the Kosovo method. Because of the accuracy and ease of the Kosovo method, it is recommended for future investigations.

Keywords: Depleted Uranium (DU); High penetration; Contaminated with DU; Genie2000; Kosovo method.

1. Introduction

DU is defined by World Health Organization (WHO) as the 'uranium remaining after removal of the enriched fraction' and contains about 99.8% ^{238}U , 0.2% ^{235}U and 0.001% ^{234}U by mass. DU is a heavy metal, produced by refining natural uranium, and is 40% less radioactive than natural uranium, also containing at least three times less ^{235}U than natural uranium [1]. Depleted uranium (DU) is a waste product of uranium enrichment and is distinguished from natural uranium by lower relative concentrations of ^{235}U (<0.7%) and ^{234}U . DU has civilian and military applications. The civilian application is in the area of radiation protection as a shield because of its high density (19.07 g/cm^3) and high atomic number ($z = 92$). It is also used as a counterweight and ballast in aircraft and yachts and as a catalyzer in chemical processes. The military applications of DU are in ammunition and as an element of guided missiles [2]. Some of these amounts of DU are used to balance of Buoying aircraft, aircraft wings, shield and fast breeder reactors to produce plutonium. Some researches were conducted in 1972 to find a way to get rid of DU by using it as bolts or as shield for tanks; because of its high density and its high penetration power when bombarding solid targets and being fired strongly, causes high pressure and temperature of about 70% of DU transfer to aerosol of ^{238}U which reacts with oxygen at

high temperature producing uranium oxides. DU is alpha emitter with radioactivity of 12500Bq/gm which is about half the activity of natural uranium (25160Bq/gm) [3]. It has high density (19.05g/cm^3), 2.54 times heavier than iron, with a high penetrating power, so it can be used for civilians and military industry. The main civilian application of DU includes counter-weights in aircraft, calorimeter, detectors, flywheels, and sinker bars [4]. In military it is used as penetrating and tanks heavy amour. The highly flammable metal fill with DU small bullet fired by aircraft is shown in figure 1.

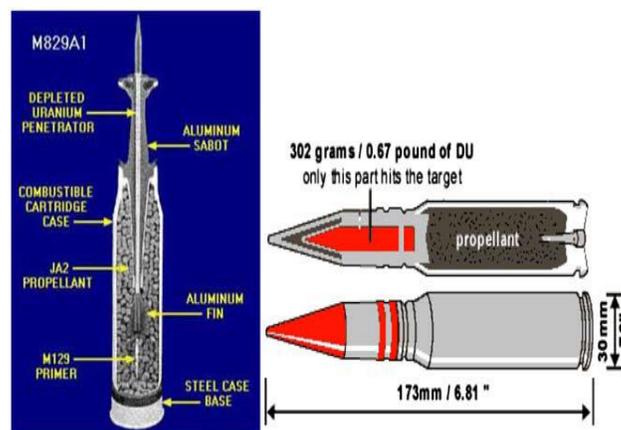


Fig. 1: Schematic diagram of a DU round (WHO 2001).

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The weight of a small bullet is approximately 300g of DU hitting the ground in a straight line; one to three meters a part, depending on the angle of the approach [5]. Some of the bullets that miss their targets fall on the ground and could be considered as serious environmental pollutants that may contaminate food, surface water resources and ground water because the corrosion penetrations in soil/water may be rapid (0.01- 0.05cm/y) [6]. After hit of a DU penetrator on a tank, a part of the DU released will be deposited on the soil surface as pieces of DU metal, fine fragments and as dust of DU oxides. The characteristics of DU particles in soil/sand from Kosovo and Kuwait contaminated during the Balkan conflict and the Gulf wars vary significantly depending on the release scenarios. Re-suspension of DU dust may occur, but DU exposure from this pathway is very low for the general population due to the low concentrations of DU involved and the high density of U-containing particles reducing potential for re-suspension [7]. The aim of this work was to investigate DU contamination in Aden governorate, Yemen by adapting Kosovo mathematical method used for assessment of contaminated soil samples.

1.1. Literature review:

A shocking number of bombs and explosives have been dropped on multiple countries of Western Asia, particularly on the Gaza Strip in Palestine [8; 9], Beirut in Lebanon [10], and Sana'a and Aden in Yemen [11]. Iraq and Afghanistan endured massive bombardment of their major cities two decades ago [12; 13]. The immediate death and maiming of the population are some of the many public health consequences of these bombardments. Other long-term adverse health consequences of such bombardments include congenital anomalies and cancers. Public exposure to persistent toxic metals that are released through bomb explosions cause spikes in congenital anomalies and cancers in targeted population's decades after cessation of bombardments [14]. Across Iraq, increases in congenital anomalies and cancers have been linked to exposure to war contamination [15].

The behavior of DU in the body is identical to that of natural uranium and, as such, there are three main exposure pathways that impact on human health: exposure to radiation, exposure to chemicals, and exposure to physical hazards. Potentially DU has both chemical and radiological toxicity, targeting organs such as the kidneys and lungs. Damage depends on both the physical and chemical nature of the DU to which the individual is exposed, and the duration of exposure [16]. Uranium oxides are insoluble and are at least 100 times smaller than a white blood cell – so when the people breathe, they inhale them; the particles go through the nose, through the olfactory and into the brain; they disrupt cognitive ability and thought processes, and damage the mood control mechanism in the brain [17]. The knowledge we gain from this investigation can help in understanding the environmental conditions in hard-to-reach areas like Aden

and Sana'a in Yemen.

2. Materials and Methods

2.1. Description of Study Area:

Aden Assoghra city area (~ 485.9Km²) is located some (363Km) southern of Sana'a, exactly located in west of Aden governorate, south of Yemen. The study area considers the most important directorate in Aden governorate, where represented more than half Aden so it is a coastal city, and contain a number of mountainous highlands formed by volcanic origin. The climate of study area is relatively hot with an average temperature a bought 27 Celsius during the days of the year and the humidity is between (73% - 62%) and is characterized by low rainfall weather. According to the results of the 2004 census, the number of population at Aden Assoghra city is (62405Souls). Aden Assoghra city contains oil refinery operating since 1954, as well as oil port. It also contains the power station that uses a heavy fuel oil and has been operating since 1981. The map of studied area is shown in Figure (2). Table (1) shows symbol and location name for the different studied regions (sites) in Aden Assoghra city for surface soil.

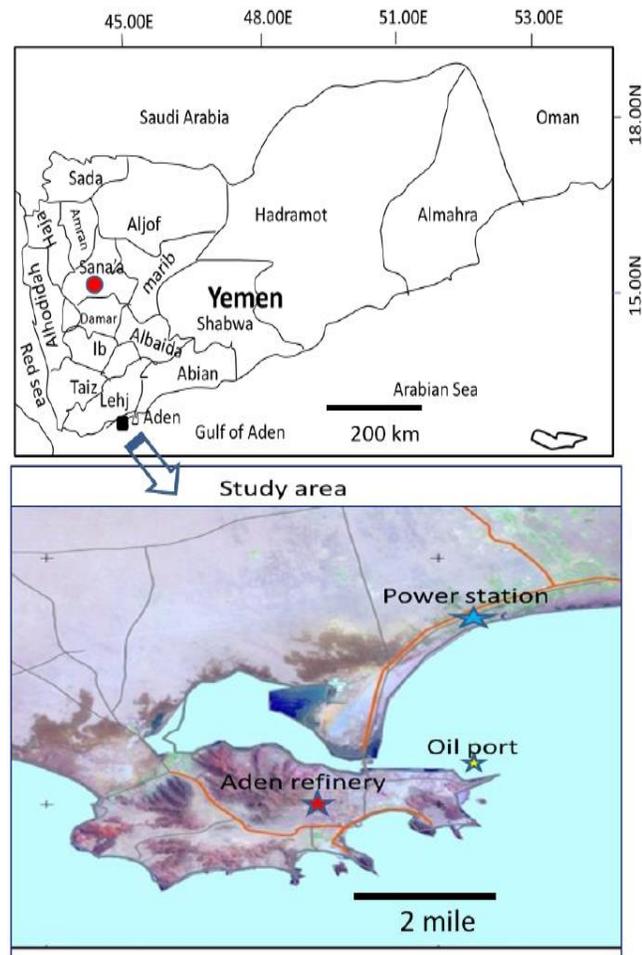


Fig. 2: Illustrates the area under study.

Table 1: Symbol, location name and Coordinates, for soil samples sites in Aden Assoghra city.

| Sample code | Type of sample | Coordinates | |
|-------------|----------------|--------------|---------------|
| | | Latitude (N) | Longitude (E) |
| MRS1 | Sandy soil | 12°45'951" | 44°53'336" |
| MRS2 | Sandy soil | 12°46'708" | 44°52'859" |
| MRS3 | Sandy soil | 12°45'190" | 44°53'336" |
| MRS4 | Sandy soil | 12°47'740" | 44°52'516" |
| MRS5 | Sandy soil | 12°44'789" | 44°51'701" |
| MRS6 | Sandy soil | 12°45'302" | 44°51'173" |
| MRS7 | Sandy soil | 12°45'819" | 44°50'341" |
| MRS8 | Sandy soil | 12°45'380" | 44°53'742" |
| MRS9 | Coastal soil | 12°49'481" | 44°49'675" |
| MRS10 | Coastal soil | 12°44'499" | 44°53'058" |
| MRS11 | Clay soil | 12°45'757" | 44°52'752" |
| MRS12 | Sandy soil | 12°44'852" | 44°54'458" |
| MRS13 | Coastal soil | 12°46'551" | 44°53'304" |
| MRS14 | Sandy soil | 12°45'891" | 44°53'564" |
| MRS15 | Sandy soil | 12°45'874" | 44°53'583" |
| MRS16 | Sandy soil | 12°45'616" | 44°53'201" |
| MRS17 | Coastal soil | 12°44'910" | 44°53'361" |

2.2. Collection and Preparation of the samples:

Seventeen environmental samples (surface soils) were collected from different sites in Aden Assoghra city, Yemen, and prepare for measuring the ²³⁴Th, ²³⁵U; ²³⁴Pa and other natural isotopes activity concentrations measurements by using gamma spectroscopy. Surface soils were collected randomly from different places within cleared area from the ground surface up to 5cm and mixed together thoroughly in order to obtain a representative sample of that area. Each sample (surface soil) was dried in an oven at 105°C and sieved through a 18mesh (equivalent 1mm) which is the optimum size enriched in heavy mineral [18]. Each sample was packed in plastic containers dimensions of 75 mm in diameter and 90 mm height. Each sample were weighed and stored for one month to ascertain establishment of secular equilibrium between ²²⁶Ra and ²³²Th with their daughter and to prevent radon loss. After attainment of secular equilibrium the samples were counted for 8-24 h depending on the concentration of the radionuclides.

2.3. Radioactivity analysis:

All the samples were measured at the nuclear physics laboratory in atomic energy organization laboratory, Sana'a, Yemen using a gamma ray spectrometer. The applied low level background gamma ray spectrometer consists basically of an HPGe detector the detector was coaxial in shape having relative efficiency 35% with respect to NaI (TI) detector and active volume of 180cm³ fitted with beryllium-end window. The detector had closed-end coaxial Gamma-ray detectors (p-type) made up of high purity germanium (HPGe) in a vertical configuration cooled by liquid nitrogen with the following

specifications: resolution (FWHM) ≤ 2.000keV and ≤ 0.925keV at 1.33MeV and 122keV, respectively, with a relative efficiency of 35%. The germanium crystal was located within a lead shield for the reduction of the environmental background. The detector is connected to preamplifier, main amplifier, analogue to digital converted (ADC) and multichannel analyzer. The system was calibrated for energy using standard point sources (⁶⁰Co, ¹³⁷Cs), and calibrated for efficiency using standard QCYB41 [19, 20]. Every sample was placed in face to face geometry the detector for 10 to 24hour for (²³⁸U) concentrations measurements. Prior to sampling counting, background were taken normally every week under the same condition of sample measurement. The spectra were analyzed by the computer software program Canberra's Genie2000 Canberra Industries, Inc, USA) for the calculation of Uranium-238. The net area under the curve for each decay isotopes of U-235, U-238, and K-40 were calculated [21].

The radioactivity concentration of ²³⁸U was determined from the photo peaks of ²³⁴Th (63.29keV) (which was verified by ²³⁵U measurement using the 163keV line). Radioactivity in the soil sample is calculated using the following equation [22]:

$$A_i = \frac{N_i}{\epsilon(E) \cdot \gamma \cdot t \cdot m} \tag{1}$$

Where:

N_i is the net gamma count in a photo-peak (background corrected), ε(E) the detector efficiency as function of gamma-ray energy, γ the number of gammas per disintegration of the given nuclide at energy E (the absolute transition probability of gamma-decay), m the sample mass (kg) and t the counting time (s).

3. Results and Discussion

To investigate the contaminations of samples, we use method that used by International Committee to detect the DU in Kosovo [3, 5] as follow:

- A.** Conversion of the radioactivity of ²³⁸U to mass percentage by dividing to 12.35Bq/kg.
- B.** From the mass percentage the percentage of ²³⁸U in background sample was subtracted to find the quantity of DU in soil samples.
- C.** The percentage of depleted uranium (X%) was found by dividing the quantity of DU by the total concentration of ²³⁸U.
- D.** According to the following equation Ru was found:

$$Ru = (0.72-0.52X) / (99.2745+0.5255X) \tag{2}$$

Where: X = the quantity of DU in soil samples, and Ru = the percentage between ²³⁵U and ²³⁸U which is equal to 0.0072 (1/R=139) when the concentration of DU= 0% or the ratio ²³⁸U/²³⁵U is equal to 0.0035 when the

concentration of DU = 100%. Contamination with DU was considered if the ratio between $^{235}\text{U}/^{238}\text{U}$ in samples was less than 0.005. [23] From gamma ray spectrums, the peaks of $^{234\text{m}}\text{Pa}$ and ^{235}U radionuclide are not seen in non-contaminated samples, but in contaminated samples these peaks were easily detected by the gamma spectrometry system [3]. From gamma ray spectrums, the peaks of $^{234\text{m}}\text{Pa}$ and ^{235}U radionuclide are not seen in non-contaminated samples, but in contaminated samples these peaks were easily detected by the gamma spectrometry system [3]. Table 2 shows the results of the specific radioactivity (Bq/kg) for the specified radionuclides for

each soil sample. From the specific radioactivity of Th^{234} and Ra^{226} the percentage between $\text{Th}^{234}/\text{Ra}^{226}$ ranged from (0.88-1.12) which proved that radiation equilibriums existed as shown in figure 3. From the specific radioactivity of ^{234}Th and $\text{Pa}^{234\text{m}}$ the percentage between $\text{Th}^{234}/\text{Pa}^{234\text{m}}$ are calculated for the contaminated samples. From Table 3 the ratio between $\text{Th}^{234}/\text{Pa}^{234\text{m}}$ in soil samples ranged between (0.83-1.24) and the ratio between ^{214}Bi and ^{214}Pb existed with the range between (0.95-1.07) indicating that these isotopes were at radiation equilibrium for the first daughter nuclide of ^{238}U series as shown in figure 4 and figure 5 [24].

Table 2: The specific radioactivity (Bq/kg) for the specified radionuclides for each soil sample.

| Radionuclides | | U+Ra+Pa | K-40 | Bi ²¹⁴ | Pb ²¹⁴ | Th-234 | U-235 | Pa-234m |
|---------------|-----------------------------------|---------|---------|-------------------|-------------------|--------|--------|---------|
| Energy (keV) | | 186.21 | 1460.75 | 609.31 | 351.92 | 63.29 | 205.31 | 1001.03 |
| MRS1 | Activity (Bq/kg) | 65.11 | 529 | 14.28 | 14.13 | 73.16 | 1.913 | - |
| | $\text{Th}^{234}/\text{Ra}^{226}$ | 1.12 | | | | | | |
| MRS2 | Activity (Bq/kg) | 61.16 | 694 | 11.89 | 12 | 59.52 | 5.258 | - |
| | $\text{Th}^{234}/\text{Ra}^{226}$ | 0.97 | | | | | | |
| MRS3 | Activity (Bq/kg) | 12.17 | 565 | 17.03 | 16.91 | 12.04 | 1.609 | - |
| | $\text{Th}^{234}/\text{Ra}^{226}$ | 0.99 | | | | | | |
| MRS4 | Activity (Bq/kg) | 10.64 | 496 | 14.99 | 15 | 10.36 | 2.238 | - |
| | $\text{Th}^{234}/\text{Ra}^{226}$ | 0.97 | | | | | | |
| MRS5 | Activity (Bq/kg) | 7.99 | 213 | 6.75 | 6.95 | 7.74 | 5.85 | - |
| | $\text{Th}^{234}/\text{Ra}^{226}$ | 0.96 | | | | | | |
| MRS6 | Activity (Bq/kg) | 15.74 | 602 | 15.8 | 15.9 | 15.64 | 1.788 | - |
| | $\text{Th}^{234}/\text{Ra}^{226}$ | 0.99 | | | | | | |
| MRS7 | Activity (Bq/kg) | 43.90 | 304 | 12.12 | 12.14 | 43.93 | 2.139 | - |
| | $\text{Th}^{234}/\text{Ra}^{226}$ | 1 | | | | | | |
| MRS8 | Activity (Bq/kg) | 38.60 | 498 | 12.4 | 12.52 | 40.21 | 2.238 | - |
| | $\text{Th}^{234}/\text{Ra}^{226}$ | 1.04 | | | | | | |
| MRS9 | Activity (Bq/kg) | 32.63 | 690 | 10.8 | 10.34 | 32.18 | 2.594 | - |
| | $\text{Th}^{234}/\text{Ra}^{226}$ | 0.98 | | | | | | |
| MRS10 | Activity (Bq/kg) | 25.71 | 434 | 11.354 | 11.62 | 25.37 | 1.949 | - |
| | $\text{Th}^{234}/\text{Ra}^{226}$ | 0.99 | | | | | | |
| MRS11 | Activity (Bq/kg) | 40.24 | 542 | 15.28 | 15.85 | 40.24 | 1.996 | - |
| | $\text{Th}^{234}/\text{Ra}^{226}$ | 1.0 | | | | | | |
| MRS12 | Activity (Bq/kg) | 51.98 | 639 | 17.34 | 17.19 | 51.61 | 0 | - |
| | $\text{Th}^{234}/\text{Ra}^{226}$ | 0.99 | | | | | | |
| MRS13 | Activity (Bq/kg) | 23.34 | 603 | 11.51 | 11.62 | 22.99 | 1.976 | - |
| | $\text{Th}^{234}/\text{Ra}^{226}$ | 0.98 | | | | | | |
| MRS14 | Activity (Bq/kg) | 65.64 | 522 | 12.32 | 12.29 | 57.61 | 2.056 | - |
| | $\text{Th}^{234}/\text{Ra}^{226}$ | 0.88 | | | | | | |
| MRS15 | Activity (Bq/kg) | 70.72 | 538 | 12.2 | 11.7 | 69.83 | 1.949 | - |
| | $\text{Th}^{234}/\text{Ra}^{226}$ | 0.98 | | | | | | |
| MRS16 | Activity (Bq/kg) | 45.42 | 553 | 15 | 14.88 | 45.88 | 1.930 | - |
| | $\text{Th}^{234}/\text{Ra}^{226}$ | 0.99 | | | | | | |
| MRS17 | Activity (Bq/kg) | 67.29 | 210 | 4.80 | 5.16 | 68.73 | 1.794 | - |
| | $\text{Th}^{234}/\text{Ra}^{226}$ | 1.02 | | | | | | |

Table 3: The percentage ratio calculated for $^{234}\text{Th}/^{234\text{m}}\text{Pa}$ in soil Samples.

| Radionuclides | | Ra-226 | K-40 | Bi ²¹⁴ | Pb ²¹⁴ | Th-234 | U-235 | Pa-234m |
|---------------|---|--------|------|-------------------|-------------------|--------|-------|---------|
| MRS1 | Activity (Bq/kg) | 65.11 | 529 | - | - | 73.16 | 1.913 | 73.94 |
| | $^{234}\text{Th}/^{234\text{m}}\text{Pa}$ | 0.99 | | | | | | |
| MRS2 | Activity (Bq/kg) | 61.16 | 694 | - | - | 59.52 | 5.258 | 60.23 |
| | $^{234}\text{Th}/^{234\text{m}}\text{Pa}$ | 0.98 | | | | | | |
| MRS3 | Activity (Bq/kg) | 12.17 | 565 | - | - | 12.04 | 1.609 | 0 |
| | $^{234}\text{Th}/^{234\text{m}}\text{Pa}$ | - | | | | | | |
| MRS4 | Activity (Bq/kg) | 10.64 | 496 | - | - | 10.36 | 2.238 | 0 |
| | $^{234}\text{Th}/^{234\text{m}}\text{Pa}$ | - | | | | | | |
| MRS5 | Activity (Bq/kg) | 7.98 | 213 | - | - | 7.74 | 5.85 | 0 |
| | $^{234}\text{Th}/^{234\text{m}}\text{Pa}$ | - | | | | | | |
| MRS6 | Activity (Bq/kg) | 15.74 | 602 | - | - | 15.64 | 1.788 | 0 |
| | $^{234}\text{Th}/^{234\text{m}}\text{Pa}$ | - | | | | | | |
| MRS7 | Activity (Bq/kg) | 43.90 | 304 | - | - | 43.93 | 2.139 | 42.24 |
| | $^{234}\text{Th}/^{234\text{m}}\text{Pa}$ | 1.04 | | | | | | |
| MRS8 | Activity (Bq/kg) | 38.60 | 498 | - | - | 40.21 | 2.238 | 39.04 |
| | $^{234}\text{Th}/^{234\text{m}}\text{Pa}$ | 1.03 | | | | | | |
| MRS9 | Activity (Bq/kg) | 32.63 | 690 | - | - | 32.18 | 2.594 | 33.43 |
| | $^{234}\text{Th}/^{234\text{m}}\text{Pa}$ | 0.96 | | | | | | |
| MRS10 | Activity (Bq/kg) | 25.71 | 434 | - | - | 25.37 | 1.949 | 0 |
| | $^{234}\text{Th}/^{234\text{m}}\text{Pa}$ | - | | | | | | |
| MRS11 | Activity (Bq/kg) | 40.24 | 542 | - | - | 40.24 | 1.996 | 41.36 |
| | $^{234}\text{Th}/^{234\text{m}}\text{Pa}$ | 0.97 | | | | | | |
| MRS12 | Activity (Bq/kg) | 51.98 | 639 | - | - | 51.61 | 0 | 53.98 |
| | $^{234}\text{Th}/^{234\text{m}}\text{Pa}$ | 0.96 | | | | | | |
| MRS13 | Activity (Bq/kg) | 23.34 | 603 | - | - | 22.99 | 1.976 | 0 |
| | $^{234}\text{Th}/^{234\text{m}}\text{Pa}$ | - | | | | | | |
| MRS14 | Activity (Bq/kg) | 65.64 | 522 | - | - | 57.61 | 2.056 | 56.62 |
| | $^{234}\text{Th}/^{234\text{m}}\text{Pa}$ | 1.02 | | | | | | |
| MRS15 | Activity (Bq/kg) | 70.72 | 538 | - | - | 69.83 | 1.949 | 84.13 |
| | $^{234}\text{Th}/^{234\text{m}}\text{Pa}$ | 0.99 | | | | | | |
| MRS16 | Activity (Bq/kg) | 45.42 | 553 | - | - | 45.88 | 1.930 | 45.42 |
| | $^{234}\text{Th}/^{234\text{m}}\text{Pa}$ | 1.01 | | | | | | |
| MRS17 | Activity (Bq/kg) | 67.29 | 210 | - | - | 68.73 | 1.794 | 55.42 |
| | $^{234}\text{Th}/^{234\text{m}}\text{Pa}$ | 1.24 | | | | | | |

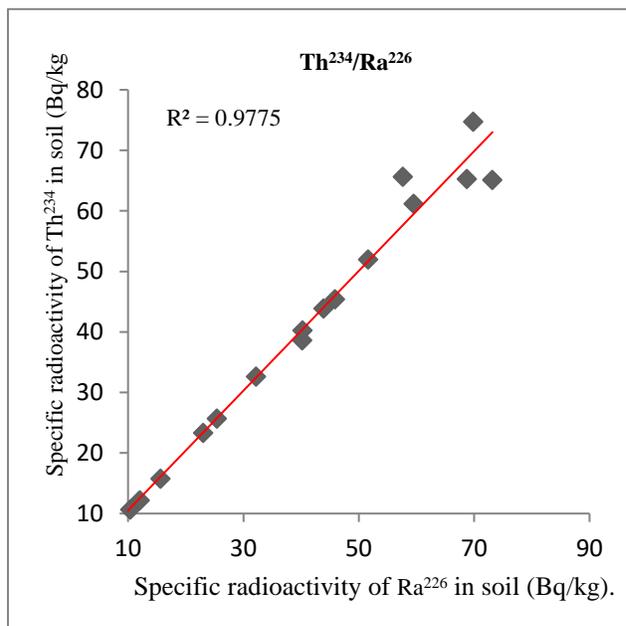


Fig. 3: Correlation plot for the activity concentrations of ^{226}Ra and ^{234}Th in the soil samples.

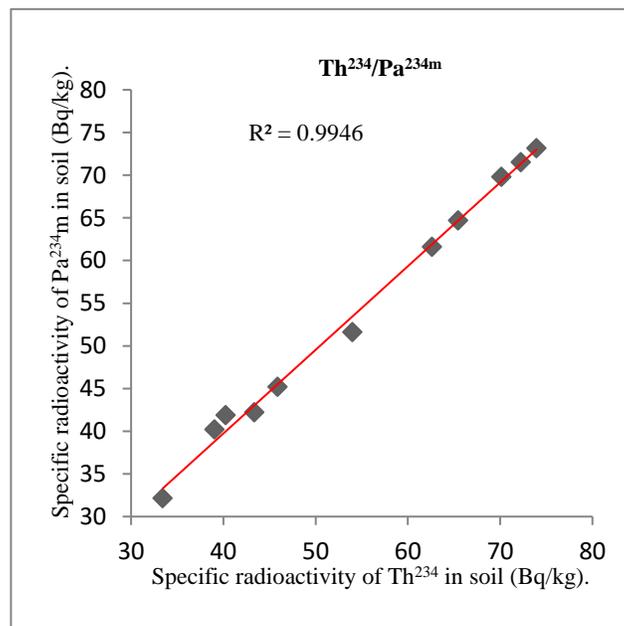


Fig. 4: Correlation plot for the activity concentrations of Th^{234} and $\text{Pa}^{234\text{m}}$ in the soil Samples.

Table 4 the percentage between $^{235}\text{U}/^{238}\text{U}$ (Ru) which has been calculated according to Kosovo method ranged between (0.003076-0.004444) for contaminated samples and (0.00510-0.00720) for uncontaminated samples with DU which is in agreement well with other findings [2, 5, 7]. The measurement by gamma-ray spectrometry system showed that eleven samples were contaminated with DU, because the percentage ratios between $^{235}\text{U}/^{238}\text{U}$ were less than 0.005, when international mathematical method, namely Kosovo, was used [3]. This contamination had taken place due to the movements of pollutants from the destroyed bullet fired by aircraft using in ammunition as metallic depleted uranium projectiles to the nearby the city soil. Comparing the results of $^{235}\text{U}/^{238}\text{U}$ it was observed that there had been an approximation in the obtained percentage according to Kosovo method. Based on the obtained results, the Kosovo method was found more useful and accurate method for DU contamination measurement [2].

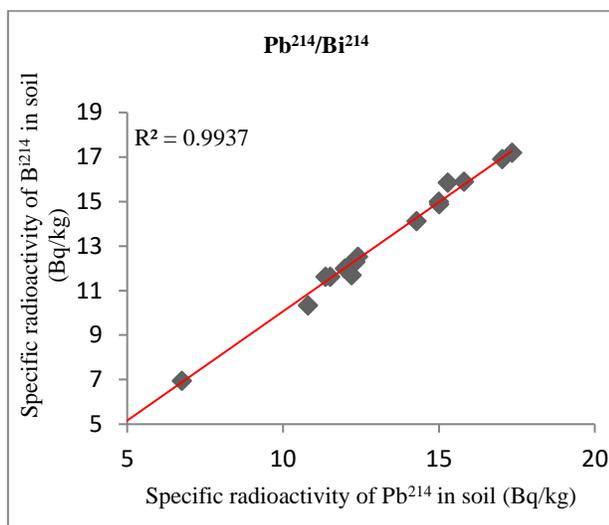


Fig. 5: Correlation plot for the activity concentrations of Pb^{214} and Bi^{214} in the soil.

Table 4: Radioactivity and concentration of ^{238}U , percentage ratio between $^{235}\text{U}/^{238}\text{U}$ and quantity of DU in soil Samples.

| Sample code | ^{238}U | ^{238}U Con. ($\mu\text{g}/\text{Kg}$) | Uranium isotopes (Bq/L) | | | | |
|---|------------------|---|-------------------------------------|--------|------------------------|--------------------------------------|----------|
| | | | DU Con. ($\mu\text{g}/\text{Kg}$) | X% | Quantity of Nat. U 1-X | Ru $^{235}\text{U} / ^{238}\text{U}$ | 1/Ru |
| MRS1 | 73.16 | 5.924 | 4.709 | 79.497 | 0.2050 | 0.003076 | 325.137 |
| MRS2 | 59.52 | 4.819 | 3.605 | 74.798 | 0.2520 | 0.003321 | 301.066 |
| MRS3 | 12.04 | 0.9751 | 0 | 0 | 1 | 0.007253 | 137.881 |
| MRS4 | 10.36 | 0.8391 | 0 | 0 | 1 | 0.007253 | 137.881 |
| MRS5 | 7.74 | 0.6269 | 0 | 0 | 1 | 0.007253 | 137.881 |
| MRS6 | 15.64 | 1.266 | 0.0518 | 4.0921 | 0.9591 | 0.007036 | 142.111 |
| MRS7 | 43.90 | 3.555 | 2.340 | 65.831 | 0.3417 | 0.0037911 | 263.772 |
| MRS8 | 40.21 | 3.256 | 2.041 | 62.696 | 0.3730 | 0.003955 | 252.814 |
| The average of background radiation = 15Bq/kg = 1.214mg/kg | | | | | | | |
| MRS9 | 32.18 | 2.605 | 1.391 | 53.386 | 0.4661 | 0.004444 | 225.0370 |
| MRS10 | 25.37 | 2.054 | 0.8397 | 40.875 | 0.5912 | 0.005100 | 196.057 |
| MRS11 | 40.24 | 3.259 | 2.044 | 62.727 | 0.3727 | 0.003954 | 252.919 |
| MRS12 | 51.61 | 4.179 | 2.964 | 70.934 | 0.2906 | 0.003524 | 283.780 |
| MRS13 | 22.99 | 1.862 | 0.6476 | 34.777 | 0.6522 | 0.005421 | 184.467 |
| MRS14 | 57.61 | 4.665 | 3.4502 | 73.963 | 0.2604 | 0.003365 | 297.153 |
| MRS15 | 69.83 | 5.654 | 4.440 | 78.519 | 0.2148 | 0.003127 | 319.818 |
| MRS16 | 45.88 | 3.715 | 2.500 | 67.306 | 0.3269 | 0.003714 | 269.259 |
| MRS17 | 68.73 | 5.565 | 4.351 | 78.175 | 0.2182 | 0.003145 | 317.988 |

4. Conclusion

The result showed that eleven of the samples were contaminated with DU and there is a good agreement with the Kosovo method. The ratio of $^{235}\text{U}/^{238}\text{U}$ has different values from (0.00244 to 0.00453) indicating the presence of the percentage of depleted uranium, the percentage of uranium and the values from 0.00244 to 0.00453 and that approved using forces DU in war in Yemen.

The war in Yemen from 2014 to up to now left a legacy of pollution with DU in many regions of Yemen. The effects of these munitions may be affecting the general health of Yemeni citizens, manifesting in an increase in cancers and birth defects. Contamination has spread widely in the air, soil and water, particularly as dust in windstorms. We echo the concerns of the Yemeni Association of Social Medicine, which called upon the United Nations and other international bodies charged with safeguarding public and environmental health, to pay serious attention to the issue

of war contamination in Yemen.

Ethics approval and consent to participate:

Not applicable. This is only an environmental study of surface soil. No data from any human subject is included in this manuscript. No ethical approval was required by the laws of the Yemeni Government for this study.

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